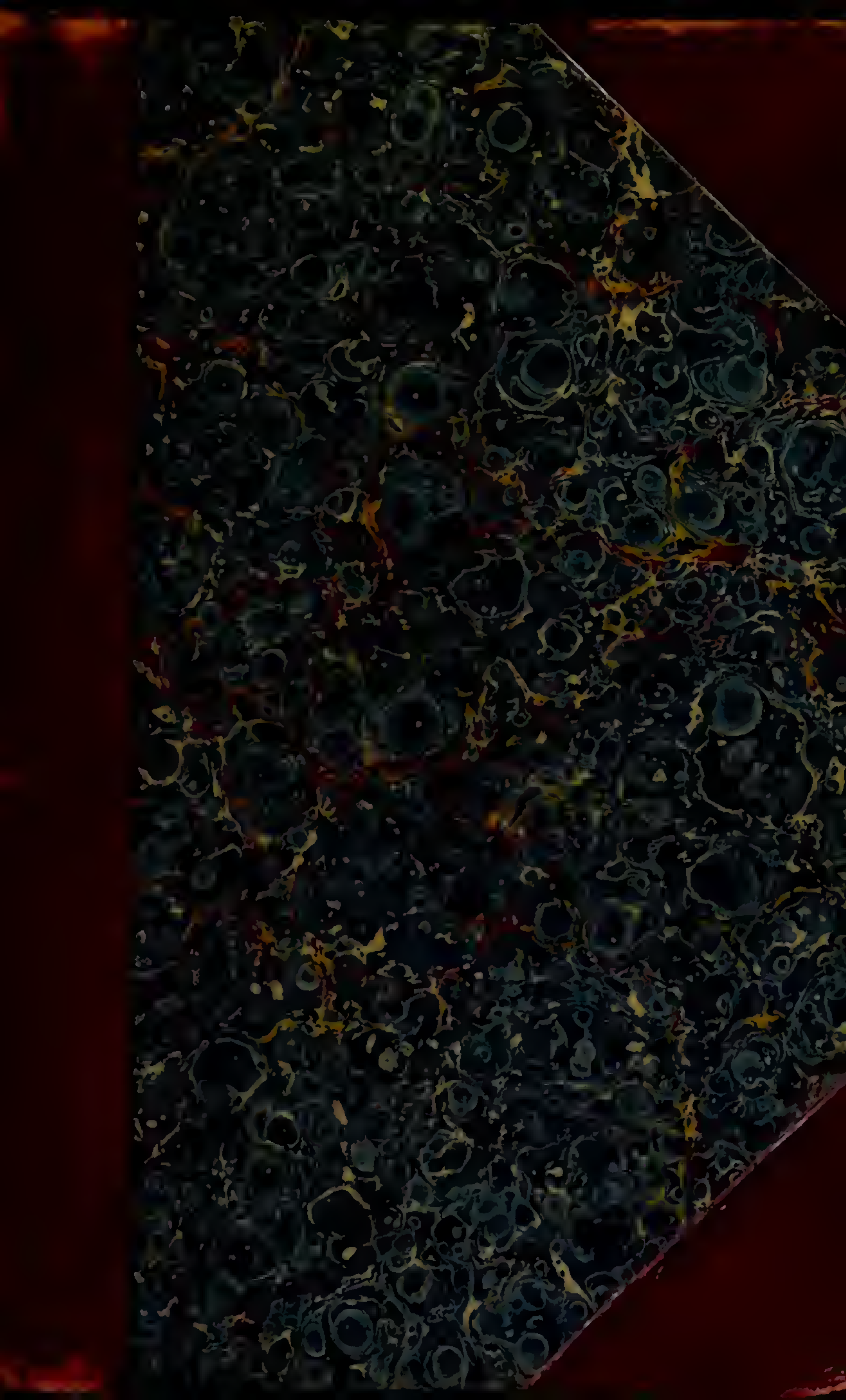

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SCIENTIFIC DIALOGUES,

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INSTRUCTION AND ENTERTAINMENT

OF

YOUNG PEOPLE:

IN WHICH

THE FIRST PRINCIPLES

OF

NATURAL AND EXPERIMENTAL

PHILOSOPHY

ARE FULLY EXPLAINED.

VOL. II. OF ASTRONOMY.

> "Converſation, with the habit of explaining the meaning "of words, and the ſtructure of common domeſtic imple"ments to children, is the ſure and effectual method of "preparing the mind for the acquirement of ſcience."
>
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CONTENTS

TO

VOL. II.

Converſation — Page

I. Of the fixed Stars - - - 1

II. Of the fixed Stars - - - 12

III. Of the fixed Stars, and Ecliptic - 21

IV. Of the Ephemeris - - 33

V. Of the Solar Syſtem - - 48

VI. Of the Figure of the Earth - 59

VII. Of the diurnal Motion of the Earth - 70

VIII. Of Day and Night - - 83

IX. Of the annual Motion of the Earth - 93

X. Of the Seaſons - - 100

XI. Of the Seaſons - - 109

XII. Of the Equation of Time - 124

XIII. Of Leap Year - - - 137

XIV. Of the Moon - - 144

XV. Of Eclipſes - - - 157

XVI. Of the Tides - - 168

XVII. Of the Harveſt Moon - - 179

XVIII. Of Mercury. - - 191
XIX. Of Venus - - - 198
XX. Of Mars - - - 207
XXI. Of Jupiter - - - 214
XXII. Of Saturn - - - 220
XXIII. Of the Herſchel Planet - - 226
XXIV. Of Comets - - - 230
XXV. Of the Sun - - - 237
XXVI. Of the fixed Stars - - 240

CONVERSATION I.

OF THE FIXED STARS.

TUTOR—CHARLES—JAMES

CHARLES. The delay occaſioned by our unuſually long walk, has afforded us one of the moſt brilliant views of the heavens that I ever ſaw.

James. It is uncommonly clear, and the longer I keep my eyes fixed upwards, the more ſtars ſeem to appear: how is it poſſible to number theſe ſtars? and yet I have heard that they are numbered, and even arranged in catalogues according to their apparent magnitudes. Pray, ſir, explain to us how this buſineſs was performed.

Tutor. This I will do, with great pleaſure, ſome time hence, but at preſent, I muſt tell you that in viewing the heavens with the naked eye, we are very much deceived as to the ſuppoſed number of ſtars that are at any time viſible. It is generally admitted, and on good authority too, that there are never more than one thouſand ſtars viſible to the ſight, unaſſiſted by glaſſes, at any one time, and in one place.

James. What! can I ſee no more than a thouſand ſtars if I look all around the heavens? I ſhould ſuppoſe there were millions.

Tutor. This number is certainly the limit of what you can at preſent behold, and that which leads you, and perſons in general to conjecture that the number is ſo much larger, is owing to an optical deception.

James. Are we frequently liable to be deceived by our ſenſes?

Tutor. We are, if we depend on them *ſingly*; but where we have an opportunity of calling in the aſſiſtance of one ſenſe to the aid of another, we are ſeldom ſubject to this inconvenience.

Charles. Do you not know that if you place a ſmall marble in the palm of the left hand, and then croſs the ſecond finger of the right hand over the firſt, and in that poſition, with your eyes ſhut, move the marble with thoſe parts of the two fingers at once, which are not accuſtomed to come into contact with any object at the ſame time, that the one marble will appear to the touch as two? In this inſtance, without the aſſiſtance of our eyes, we ſhould be deceived by the ſenſe of feeling.

Tutor. This is to the point, and ſhews that the judgment formed by means of a ſingle ſenſe is not always to be depended upon.

James. I recollect the experiment very well, we had it from papa, a great while ago. But that has nothing to do with the falſe judgment which we are ſaid to form about the number of ſtars.

Tutor. You are right; it does not immediately concern the ſubject before us, but it may be uſeful as affording a leſſon of modeſty, by inſtructing us that we ought not to cloſe our minds againſt new evidence that may be offered upon any topic, notwithſtanding the opinions we may have already formed. You ſay that you ſee millions of ſtars, whereas the ableſt aſtronomers aſſert, that with the naked eye you cannot at one time ſee ſo many as a thouſand.

Charles. I ſhould indeed have thought with my brother, had you not aſſerted the contrary; and I am anxious to know how the deception happens, for I am ſure there muſt be a great deception ſomewhere, if I do not at this time behold very many thouſands of ſtars in the heavens.

Tutor. You know that we ſee objects only by means of the rays of light which proceed from them in every direction. And you muſt, for the preſent, give me credit, when I tell you that the diſtance of the fixed ſtars from us is immenſely great, conſequently the rays of light have to travel this diſtance, in the courſe of which, eſpecially in their passage through our atmoſphere, they are ſubject to numberleſs *reflections* and *refractions.* By means of theſe, other rays of light come to the eye, every one of which, perhaps, impreſſes upon the mind the idea of ſo many ſeparate ſtars. Hence ariſes that optical fallacy by which we are led to believe the ſtars which we behold are innumerable.

James. I ſhould like to ſee an experiment to confirm this.

Tutor. I have no objection:—in every caſe you ought to require the beſt evidence that the ſubject will admit of;

To aſk or ſearch I blame thee not, for heaven
Is as the book of God before thee ſet,
Wherein to read his wondrous works, and learn
His ſeaſons, hours, or days, or months, or years.
MILTON.

I will ſhew you two experiments which will go a good way to remove the difficulty. But, for this purpoſe, we muſt ſtep into the houſe.

Here are two common looking glaſſes, which, philoſophically ſpeaking, are *plain mirrors.* I place them in ſuch a manner on the table that they ſupport one another from falling by meeting at the tops. I now place this half-crown between them, on a book, to raiſe it a little above the table. Tell me how many pieces of money you would ſuppoſe there were, if you did not know that I had uſed but one.

James. There are ſeveral in the glaſſes.

Tutor. I will alter the poſition of the glaſſes a little, by making them almoſt parallel to one another; now look into them, and ſay what you ſee.

James. There are more half-crowns now than there were before.

Tutor. It is evident then, that by *reflection* only, a ſingle object, for I have made uſe of but one half-crown, will give you the idea of a vaſt number.

Charles. If a little contrivance had been uſed to conceal the method of making the experiment, I ſhould not have believed but that there had been ſeveral half-crowns inſtead of one.'

Tutor. Bring me your multiplying glaſs; look through it at the candle: how many do you ſee? or rather how many candles ſhould you ſuppoſe there were, did you not know that there was but one on the table?

James. A great many, and a pretty ſight it is.

Charles. Let me ſee; yes, there are: but I can eaſily count them; there are ſixteen.

Tutor. There will be juſt as many images of the candle, or any other object at which you look, as there are different ſurfaces on your glaſs. For by the principle of *refraction*, the image of the candle is ſeen in as many different places as the glaſs has ſurfaces; conſequently, if inſtead of 16 there had been 60, or, if they could have been cut and poliſhed ſo ſmall; 600, then the ſingle candle would have given you the idea of 60, or 600. What think you now about the ſtars?

James. Since I have ſeen that *reflection* and *refraction* will each, ſingly, afford ſuch optical deceptions, I can no longer doubt, but that, if both theſe cauſes are combined as you ſay they are with reſpect to the rays of light coming from the fixed ſtars, a thouſand real luminaries may have the power of exciting in my mind the idea of millions.

Tutor. I will mention another experiment, for which you may be prepared againſt the next fair ſtar-light night. Get a long narrow tube, the longer and narrower the better, provided its weight does not render it unmanageable: examine through it any one of the largeſt fixed ſtars; which are called ſtars of the *firſt* magnitude, and you will find that though the tube takes in as much ſky as would contain many ſuch ſtars, yet that the ſingle one at which you are looking, is ſcarcely viſible, by the few rays which come *directly* from it: this is another proof that the brilliancy of the heavens, is much more owing to *reflected* and *refracted* light, than to the direct rays flowing from the ſtars.

CONVERSATION II.

Of the Fixed Stars.

CHARLES. Another beautiſul evening preſents itſelf, ſhall we take the advantage which it offers of going on with our aſtronomical lectures?

Tutor. I have no objection, for we do not always enjoy ſuch opportunities as the brightneſs of the preſent evening affords.

James. I wiſh very much to know how to diſtinguiſh the ſtars, and to be able to call them by their proper names.

Tutor. This you may very ſoon learn; a few evenings, well improved, will enable you to diſtinguiſh all the ſtars of the firſt magnitude which are viſible, and all the relative poſitions of the different conſtellations.

James. What are conſtellations, Sir?

Tutor. The antients, that they might the better diſtinguiſh and deſcribe the ſtars, with regard to their ſituation in the heavens, divided them into conſtellations, that is ſyſtems of ſtars, each ſyſtem conſiſting of ſuch ſtars as were near to each other, giving them the names of ſuch men or things, as they fancied the ſpace which they occupied in the heavens repreſented.

Charles. Is it then perfectly arbitrary that one collection is called the *great bear*, another *the dragon*; a third, *Hercules*, and ſo on?

Tutor. It is; and though there have been additions to the number of ſtars in each conſtellation, and various new conſtellations invented by modern aſtronomers, yet the original diviſion of the ſtars into theſe collections, was one of thoſe few arbitrary inventions which has deſcended without alteration, otherwiſe than by addition, from the days of Ptolemy down to the preſent time.——Do you know how to find the four Cardinal points as they are uſually called, the North, South, Weſt, and Eaſt?

James. O yes, I know, that if I look at the ſun at twelve o'clock at noon, I am alſo looking to the ſouth where he then is; my back is towards the north; the weſt is on my right hand, and the eaſt on my left.

Tutor. But you muſt learn to find theſe points without the aſſiſtance of the ſun; if you wiſh to be a young aſtronomer.

Charles. I have often heard of the *north pole ſtar;* that will perhaps anſwer the purpoſe of the ſun, when he has left us.

Tutor. You are right; do you ſee thoſe ſeven ſtars which are in the conſtellation of the *Great Bear;* ſome people have ſuppoſed their poſition will aptly repreſent a *plough;* others ſay, that they are more like a *waggon and horſes;*—the four ſtars repreſenting the body of the waggon, and the other three the horſes, and hence they are called by ſome the plough, and by others they are called Charles's wain or waggon. Here is a drawing of it; (Plate I. Fig. 1.) *a b d g* repreſent the four ſtars, and *e z* B the other three.

Charles. What is the ſtar P?

Tutor. That repreſents the polar ſtar to which you juſt now alluded; and you obſerve, that if a line were drawn through the ſtars *b*, and *a*, and produced far enough, it would nearly touch it.

James. Let me look in the heavens for it by this guide. There it is, I ſuppoſe; it ſhines with a ſteady, and rather dead kind of light, and it appears to me, that it would be a little to the right of the line paſſing through the ſtars *b* and *a*.

Tutor. It would, and theſe ſtars are generally known by the name of the *pointers*, becauſe they point to *p* the north pole, which is ſituated a little more than two degrees from the ſtar P.

Charles. Is that ſtar always in the ſame part of the heavens?

Tutor. It may be conſidered as uniformly maintaining its poſition, while the other ſtars ſeem to move round it as a center. We ſhall have occaſion to refer to this ſtar again; at preſent, I have directed your attention to it, as a proper method of finding the cardinal points by ſtar-light.

James. Yes, I underſtand now, that if I look to the north, by ſtanding with my face to that ſtar, the ſouth is at my back, on my right hand is the eaſt, and the weſt on my left.

Tutor. This is one important ſtep in our aſtronomical ſtudies; but we can make uſe of theſe ſtars as a kind of ſtandard, in order to discover the names and poſitions of others in the heavens.

Charles. In what way muſt we proceed in this buſineſs?

Tutor. I will give you an example or two: conceive a line drawn from the ſtar *z*, leaving B a little to the left, and it will paſs through that very brilliant ſtar near the horizon towards the weſt.

James. I ſee the ſtar, but how am I to know its name?

Tutor. Look on the celeſtial globe for the ſtar *z*, and ſuppoſe the line drawn on the globe, as we conceived it done in the heavens, and you will find the ſtar, and its name.

Charles. Here it is;—its name is Arcturus.

Tutor. Take the figure, (Fig. 1.) and place Arcturus at A, which is its relative poſition, in reſpect to the conſtellation of the Great Bear. Now, if you conceive a line drawn through the ſtars *g* and *b*, and extended a good way to the right, it will paſs juſt above another very brilliant ſtar. Examine the globe as before, and find its name.

Charles. It is *Capella*, the *goat.*

Tutor. Now, whenever you ſee any of theſe ſtars, you will know where to look for the others without heſitation.

James. But do they never move from their places?

Tutor. With reſpect to us, they ſeem to move together with the whole heavens. But they always remain in the ſame relative poſition, with reſpect to each other. Hence, they are called *fixed* ſtars, in oppoſition to the *planets*, which, like our earth, are continually changing their places, both with regard to the fixed ſtars, and to themſelves alſo.

Charles. I now underſtand pretty well the method of acquiring a knowledge of the names and places of the ſtars.

Tutor. And with this, we will put an end to our preſent converſation.

CONVERSATION III.

Of the Fixed Stars, and Ecliptic.

TUTOR. I dare ſay that you will have no difficulty in finding the north polar ſtar as ſoon as we go into the open air.

James. I ſhall at once know where to look for that and the other ſtars which you pointed out laſt night, if they have not changed their places.

Tutor. They always keep the ſame poſition, with reſpect to each other, though their ſituation, with regard to the heavens, will be different at different ſeaſons of the year, and in different hours of the night. Let us go into the garden.

Charles. The ſtars are all in the ſame place as we left them laſt evening. Now, Sir, if we conceive a ſtraight line drawn through the two ſtars in the plough, which, in your figure, (Plate I. Fig. 1.) are marked *d* and *g*, and to extend a good way down, it will paſs, or nearly paſs through a very bright ſtar, though not ſo bright as *Arcturus* or *Capella*, what is that called?

Tutor. It is a ſtar of the ſecond magnitude, and if you refer to the celeſtial globe, in the ſame way as you were inſtructed laſt night, you will find it is called *Regulus*, or *Cor*

Leonis, the *Lion's heart.* By this method you may quickly diſcover the names of all the principal ſtars, and afterwards, with a little patience, you will eaſily diſtinguiſh the others, which are leſs conſpicuous.

Charles. But they have not all names; how are they ſpecified?

Tutor. If you look on the globe, you will obſerve, that they are diſtinguiſhed by the different letters of the Greek Alphabet; and in thoſe conſtellations, in which there are ſtars of different apparent magnitudes, the largeſt is α alpha, the next in ſize β beta, the third γ gamma, the fourth δ delta, and ſo on.

James. Is there any particular reaſon for this?

Tutor. The adoption of the characters of the Greek alphabet, rather than any other, was perfectly arbitary; it is, however, of great importance, that the ſame characters ſhould be uſed in general by aſtronomers of all countries, for by this means the ſcience is in poſſeſſion of a ſort of univerſal language.

Charles. Will you explain how this is?

Tutor. Suppoſe an aſtronomer in North America, Aſia, or any other part of the earth, obſerve a comet in that part of the heavens where the conſtellation of the *plough* is ſituated, and he wiſhes to deſcribe it to his friend in Great Britain, in order that he may know, whether it was ſeen by the inhabitants of this iſland. For this purpoſe, he has only to mention the time when he diſcovered it; its poſition, as neareſt to ſome one of the ſtars, calling it by the Greek letter, by which it is deſignated; and the courſe which it took from one ſtar towards another. Thus he might ſay, that on ſuch a time he ſaw a comet near δ in the Great Bear, and that its courſe was directed from δ to β, or any other as it happens.

Charles. Then, if his friend here had ſeen a comet at the ſame time, he would, by this means know, whether it was the ſame or a different comet?

Tutor. Certainly, and hence you perceive of what importance it is, that aſtronomers in different countries ſhould agree to mark the ſame ſtars and ſyſtems of ſtars by the ſame characters. But to return to that ſtar, to which you juſt called my attention, the *cor leonis*, it is not only a remarkable ſtar, but its poſition is alſo remarkable, it is ſituated in the *ecliptic*.

James. What is that, ſir?

Tutor. The *ecliptic* is an imaginary great circle in the heavens, which the ſun *appears* to deſcribe in the courſe of a year. If you look on the celeſtial globe, you will ſee it marked with a *red* line, perhaps an emblem of the fierce heat communicated to us by that body.

James. But the ſun ſeems to have a circular motion in the heavens every day.

Tutor. It does; and this is called its apparent *diurnal*, or daily motion, which is very different from the path it appears to traverſe in the courſe of a year. The *former* is obſerved by the moſt inattentive ſpectator, who cannot but know, that the ſun is ſeen every morning in the Eaſt, at noon in the South, and in the evening in the Weſt, but the knowledge of the *latter* muſt be the reſult of patient obſervation.

Charles. And what is the *green* line which croſſes it?

Tutor. It is called the *Equator*; this is an imaginary circle belonging to the earth, which you muſt take for granted, a little longer, is of a globular form. If you can conceive the plane of the terreſtrial equator to be produced to the ſphere of the fixed ſtars, it would mark out a circle in the heavens, called the *celeſtial equator* or *equinoctial*, which would cut the *ecliptic* in two points.

James. Can we trace the circle of the *ecliptic* in the heavens?

Tutor. It may be done with tolerable accuracy by two methods; *firſt*, by obſerving ſeveral remarkable fixed ſtars, to which the moon in its courſe ſeems to approach. The *ſecond* method is by obſerving the places of the planets.

Charles. Is the moon then always in the ecliptic?

Tutor. Not exactly ſo; but it is always either in the ecliptic, or within five degrees and a third of it on one ſide or the other. The planets alſo, by which I mean, Mercury, Venus, Mars, Jupiter, Saturn, and the Herſchel, are never more than eight degrees distant from the line of the ecliptic.

James. How can we trace this line, by help of the fixed ſtars?

Tutor. By comparing the ſtars in the heavens, with their repreſentatives on the artificial globe, a practice which may be readily acquired, as you have ſeen. I will mention to you the names of thoſe ſtars, and you may firſt find them on the globe, and then refer to as many of them as are now viſible in the heavens. The firſt is in the *Ram's* horn called *α Arietis*, about ten degrees to the *north* of the ecliptic; the ſecond is the *ſtar Aldebaran* in the Bull's eye, ſix degrees *ſouth* of the ecliptic.

Charles. Then if at any time I ſee theſe two ſtars, I know that the ecliptic runs between them, and nearer to Aldebaran, than to that in the Ram's horn.

Tutor. Yes: now carry your eye eaſtward to a diſtance ſomewhat greater from Aldebaran, than that is eaſt of α Arietis, and you will perceive two bright ſtars at a ſmall diſtance from one another called *Caſtor* and *Pollux;* the lower one, and that which is leaſt brilliant is Pollux, ſeven degrees on the north ſide of the ecliptic. Following the ſame tract, you will come to *Regulus*, or the *cor leonis*, which I have already obſerved is in the line of the ecliptic. Beyond this, and only two degrees ſouth of that line, you will find the beautiful ſtar in the virgin's hand, called *Spica Virginis.* You then arrive at *Antares*, or the *Scorpion's heart.* five degrees on the ſame ſide of the ecliptic. Afterwards you will find α *Aquilæ*, which is ſituated nearly thirty degrees north of the ecliptic: and farther on is the ſtar *Fomahaut* in the fiſh's mouth, about as many degrees ſouth of that line. The ninth and laſt of theſe ſtars is *Pegaſus*, in the wing of the flying-horſe, which is north of the ecliptic nearly twenty degrees.

James. Upon what account are theſe nine ſtars particularly noticed?

Tutor. They are ſelected as the moſt conſpicuous ſtars near the moon's orbit, and are conſidered as proper ſtations, from which the moon's diſtance is calculated for every three hours of time: and hence are conſtructed thoſe tables in the *Nautical Almanac*, by means of which navigator, in their moſt diſtant voyages are enabled to eſtimate on the trackleſs ocean, the particular part of the globe on which they are.

Charles. What do you mean by the Nautical Almanac?

Tutor. It is a kind of National Almanac, intended chiefly for the uſe of perſons traverſing the mighty ocean. It was begun in the year 1767, by Dr. Maſkelyne the Aſtronomer Royal; and is publiſhed by anticipation for ſeveral years beforehand, for the convenience of ſhips going out upon long voyages. This work has been found eminently important in the courſe of the late voyages round the world for making diſcoveries.

CONVERSATION IV.

Of the Ephemeris.

CHARLES. Your ſecond method of tracing the ecliptic, was by means of the poſition of the planets: will you explain that now?

Tutor. I will; and to render you perfectly qualified for obſerving the ſtars, I will devote the preſent converſation to the purpoſe of explaining the uſe of White's Ephemeris, a little book which is publiſhed annually, and which is a neceſſary companion to every young aſtronomer.

James. Muſt we underſtand all this to ſtudy the ſtars?

Tutor. You muſt; or ſome other book of the ſame kind, if you would proceed on the beſt and moſt rational plan. Beſides, when you know the uſe of this book, which you will completely with half an hour's attention, you have nothing more to do in order to find the poſition of the planets at any day of the year, than to turn to that day in the Ephemeris, and you will inſtantly be directed to thoſe parts of the heavens, in which the different planets are ſituated. Turn to the ſecond page.

Charles. Here the aſtronomical characters are explained.

Tutor. The firſt twelve are the repreſentatives of the ſigns into which the circle of the ecliptic is divided, called alſo the twelve ſigns of the *Zodiac.*

♈ Aries.
♉ Taurus.
♊ Gemini.
♋ Cancer.
♌ Leo.
♍ Virgo.
♎ Libra.
♏ Scorpio.
♐ Sagittarius.
♑ Capricorn.
♒ Aquarius.
♓ Piſces.

Every circle connected with this ſubject is ſuppoſed to be divided into 360 parts, called degrees, and ſince that of the ecliptic is alſo divided into 12 ſigns, each ſign muſt contain 30 degrees. Aſtronomers ſubdivide each degree into minutes and ſeconds, thus if I would expreſs an angle of 25 degrees, 11 minutes and 45 ſeconds, I ſhould write 25°. . 11′. . 45″. Or, if I would expreſs the ſituation of the ſun for the firſt of Janury, 1800, I look into the ephemeris and find it in Capricorn, or ♑ 10°. . 56′. . 38″.

James. What do you mean by the Zodiac?

Tutor. It is a broad circle or belt ſurrounding the heavens, about ſixteen degrees wide; along the middle of which runs the ecliptic. The term Zodiac is derived from a Greek word ſignifying an animal, becauſe each of the twelve ſigns formerly repreſented ſome animal; that which we now call Libra, being by the ancients reckoned a part of Scorpio.

James. Why are the ſigns of the Zodiac called by the ſeveral names of Aries, Taurus, Leo, &c. I ſee no likeneſs in the heavens, to Rams, or Bulls, or Lions, which are the Engliſh words for thoſe Latin ones.

Tutor. Nor do I; nevertheleſs, the ancients ſaw, by the help of a ſtrong imagination, a ſimilarity between thoſe animals, and the places which certain ſyſtems of ſtars took up in the heavens, and gave them the names which have continued to this day.

Charles. Perhaps theſe were originally invented, in the ſame way as we ſometimes figure to our imagination, the appearances of men, beaſts, ſhips, trees, &c. in the flying clouds or in the fire.

Tutor. They might poſſibly have no better authority for their origin. At any rate it will be uſeful for you to have the names of the twelve ſigns in your memory, as well as the order in which they ſtand: I will therefore repeat ſome lines written by Dr. Watts, in which they are expreſſed in Engliſh, and will be eaſily remembered:

The *Ram*, the *Bull*, the *heavenly Twins*,
And next the *Crab*, the *Lion* ſhines,
The *Virgin* and the *Scales*;
The *Scorpion*, *Archer*, and Sea-*Goat*,
The *Man* that holds the *watering* pot,
And *Fiſh* with glittering tails.

Charles. We come now to the characters placed before the planets.

Tutor. Theſe, like the former, are but a kind of ſhort-hand characters, which, it is eſteemed eaſier to write, than the names of the planets at length. They are as follow.

♅ The Herſchel.
♄ Saturn.
♃ Jupiter.
♂ Mars.
⊖ The Earth.
☉ The Sun.
♀ Venus.
☿ Mercury.
☽ The Moon.

With the other characters you have no need to trouble yourſelves, till you come to calculate eclipſes, and conſtruct aſtronomical tables, a labour which may be deferred for ſome years to come. Turn to the eighth page.

James. Have we no concern with the intermediate pages between the ſecond and eighth?

Tutor. They do not contain any thing that requires explanation. In the eighth page, after the common almanac for January, the two firſt columns point out the exact time of the ſun's riſing and ſetting at London: thus on the 10th day of January he riſes at 58 minutes after 7 in the morning, and ſets at 2 minutes paſt 4 in the afternoon. The third column gives the *declination* of the ſun.

James. What is that, Sir?

Tutor. The *declination* of the ſun, or of any heavenly body, is its diſtance from the imaginary circle in the heavens, called the *equinoctial.* Thus you obſerve that the ſun's declination on the firſt of January is 23°. . 4′ ſouth; or, it is ſo many degrees ſouth of the imaginary *equator.* Turn to March 1803, and you will ſee that between the 20th and 21ſt days it is in the equator, for at 12 o'clock at noon on the 20th it is only 25′ ſouth, and at the ſame hour on the 21ſt it is 1′ north of that line: and when it is in the equator, then it has no declination.

Charles. Do aſtronomers always reckon from 12 o'clock at noon?

Tutor. They do; and hence the aſtronomical day begins 12 hours *later* than the day according to common reckoning: and therefore the declination, longitude, latitude, &c. of the ſun, moon, and planets, are always put down for 12 o'clock at noon of the day to which they are oppoſite. Thus the ſun's declination for the 16th of January at 12 o'clock is 20°.. 56′ ſouth.

Charles. Is that becauſe it is the commencement of the aſtronomical day, though in common life it be called 12 o'clock?

Tutor. It is. The three next columns contain the moon's declination, the time of her riſing and ſetting, and the time of her *ſouthing*, or when ſhe comes to the meridian or ſouth part of the heavens.

Charles. Does ſhe not come to the ſouth at noon as well as the ſun?

Tutor. No; the moon never comes to the meridian at the ſame time as the ſun, but at the time of new moon. And this circumſtance takes place at every new moon, as you may ſee by caſting your eye down the ſeveral columns in the ephemeris which relate to the moon's ſouthing.

The glory, the changes, and the motion of the moon, are beautifully deſcribed in the following lines:

By thy command the Moon, as day-light fades,
Lifts her broad circle in the deep'ning ſhades;
Array'd in glory, and enthron'd in light,
She breaks the ſolemn terrors of the night;
Sweetly inconſtant in her varying flame,
She changes ſtill, another, yet the ſame!
Now in decreaſe, by ſlow degrees ſhe ſhrouds
Her fading luſtre in a veil of clouds;

Now of increaſe, her gathering beams diſplay
A blaze of light, and give a paler day;
Ten thouſand ſtars adorn her glittering train,
Fall when ſhe falls, and riſe with her again;
And o'er the deſerts of the ſky unfold
Their burning ſpangles of ſidereal gold:
Through the wide heavens ſhe moves ſerenely bright,
Queen of the gay attendants of the night;
Orb above orb in ſweet confuſion lies,
And with a bright diſorder paints the ſkies.

BROOME.

James. What do you ſay of the 7th column;—*the clock before the ſun?*

Tutor. A full explanation of that muſt be deferred till we come to ſpeak of the *equation of time;* at preſent it will be ſufficient for you to know that if you are in poſſeſſion of a very accurate and well regulated clock, and alſo of an excellent ſun-dial, they will be together only four days in a year; now this 7th column in the ephemeris points out how much the clock is before the ſun; or the ſun before the clock for every day in the year. On *twelfth-day* 1803 for inſtance, the clock is faſter than the ſun by 6 minutes: but if you turn to *May-day* you will find that the clock is 2′. . 59″ ſlower than the ſun,

James. What are the four days in the year when the clock and dial are together?

Tutor. About the 15th of April; the 15th of June; the firſt of September; and Chriſtmas-day.

Charles. By this table then we may regulate our clocks and watches.

James. In what manner?

Charles. Examine on any particular day the clock or watch, and dial at the ſame time, ſay 12 o'clock, and obſerve whether the difference between them anſwer to the difference ſet down in the table, oppoſite to the day of obſervation. Thus on the 12th of March 1803 the clock will not ſhew true time, unleſs it be 10′.. 12″ before the dial, or when the dial is 12 o'clock it muſt be 10′.. 12″ paſt 12 by the clock or watch.

Tutor. Well, let us proceed to the next page. The three firſt *ſhort* columns, relating only to the duration of day-light and twilight, require no explanation: the fourth we ſhall paſs over for the preſent; and the remaining five give the *latitude* of the planets.

James. What do you mean by the latitude, Sir?

Tutor. The latitude of any heavenly body is its diſtance from the *ecliptic* north or ſouth. The latitude of *Venus*, on new-year's day 1803, is 4° north, *Charles.* Then the *latitude* of heavenly bodies, has the ſame reference to the *ecliptic*, that *declination* has to the equator?

Tutor. It has.

James. But I do not ſee any table of the ſun's latitude.

Tutor. I dare ſay your brother can give you a reaſon for this.

Charles. Since the latitude of a heavenly body is its *diſtance from* the ecliptic, and ſince the ſun is always in the ecliptic, therefore he can have no latitude.

Tutor. The *longitude* of the ſun and planets is the only thing in this page that remains to be explained. The longitude of a heavenly body is its diſtance from the firſt point of the ſign Aries, and it is meaſured on the ecliptic. It is uſual, however, as you obſerve in the ephemeris, to expreſs the longitude of a heavenly body by the degree of the ſign in which it is. In this way the ſun's longitude on the firſt of January, 1803, is in Capricorn 10°.. 12′.. 23″; that of the moon in Aries, 20°.. 26′; that of Jupiter is in Libra 5°.. 22′; and ſo on.

Charles. There are ſome ſhort columns at the bottom of the former page that you have omitted.

Tutor. The uſe of theſe will be better underſtood when we come to converſe reſpecting the planets*.

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* For the explanation of Heliocentric Longitude, ſee Converſation XX.

CONVERSATION V.

Of the Solar Syſtem.

TUTOR. We will now proceed to the deſcription of the *Solar Syſtem.*

James. Of what does that conſiſt, Sir?

Tutor. It conſiſts of the ſun, and planets, with their ſatellites or moons. It is called the *Solar Syſtem,* from *Sol* the ſun, becauſe the ſun is ſuppoſed to be fixed in the center, while the planets, and our earth among them, revolve round him at different diſtances.

Charles. But are there not ſome people who believe that the ſun goes round the earth?

Tutor. Yes, it is an opinion embraced by the generality of perſons, not accuſtomed to reaſon on theſe ſubjects. It was adopted by Ptolemy, who ſuppoſed the earth perfectly at reſt, and the ſun, planets, and fixed ſtars to revolve about it every twenty-four hours.

James. And is not that the moſt natural ſuppoſition?

Tutor. If the ſun and ſtars were ſmall bodies in compariſon of the earth, and were ſituated at no very great diſtance from it, then the ſyſtem maintained by Ptolemy and his followers might appear the moſt probable.

James. Are the ſun and ſtars very large bodies then?

Tutor. The ſun is more than a million of times larger than the earth which we inhabit, and many of the fixed ſtars are probably much larger than he is.

Charles. What is the reaſon, then, that they appear ſo ſmall?

Tutor. This appearance is cauſed by the immenſe diſtance there is between us and theſe bodies. It is known with certainty, that the ſun is more than 95 millions of miles diſtant from the earth, and the neareſt fixed ſtar is probably more than two hundred thouſand times farther from us than even the ſun himſelf*.

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* The young reader, will when he is able to manage the ſubject, ſee this clearly de-

Charles. But we can form no conception of ſuch diſtances.

Tutor. We talk of millions, with as much eaſe as of hundreds or tens, but it is not, perhaps, poſſible for the mind to form any adequate conceptions of ſuch high numbers. Several methods have been adopted to aſſiſt the mind in comprehending the vaſtneſs of theſe diſtances. You have ſome idea of the ſwiftneſs with which a cannon-ball proceeds from the mouth of the gun?

James. I have heard at the rate of eight miles in a minute.

Tutor. And you know how many minutes there are in a year?

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monſtrated by a ſeries of propoſitions in the 5th book of Dr. Enfield's Inſtitutes of Natural Philoſophy. Second Edition. See p. 346 to the end of book V.

James. I can eaſily find that out, by multiplying 365 days by 24 for the number of hours, and that product by 60, and I ſhall have the number of minutes in a year, which number is 525,600.

Tutor. Now if you divide the diſtance of the ſun from the earth by the number of minutes in a year multiplied by 8, becauſe the cannon-ball travels at the rate of 8 miles in one minute, and you will know how long any body iſſuing from the ſun, with the velocity of a cannon-ball, would employ in reaching the earth.

Charles. If I divide 95,000,000 by 525,600, multiplied by 8 or 4,204,800, the anſwer will be more than 22, the number of years taken for the journey.

Tutor. Is it then probable that bodies ſo large, and at ſuch diſtances from the earth, ſhould revolve round it every day?

Charles. I do not think it is.—Will you, Sir, go on with the deſcription of the *Solar System*?

Tutor. According to this ſyſtem, the ſun is in the center, about which the planets revolve from *weſt to eaſt*, according to the order of the ſigns in the ecliptic; that is, if a planet is ſeen in Aries, it advances to Taurus, then to Gemini, and ſo on.

James. How many planets are there belonging to the ſun?

Tutor. At preſent there have been diſcovered no more than ſeven. C (Plate 1. Fig. 2.) is the ſun, the neareſt to which *Mercury* revolves in the circle *a;* next to him is the beautiful planet *Venus,* who performs her revolution in the circle *b;* then comes the *Earth* in *t;* next to which is *Mars* in *e;* then *Jupiter* in the circle *f;* afterwards *Saturn* in *g;* and far beyond him the *Herſchel* planet performs his revolution in the circle *h.* Do you recollect the lines in Thomſon's Summer?

——— ——— ——— and thou, O Sun;
Soul of ſurrounding worlds! in whom beſt ſeen
Shines out thy MAKER! may I ſing of thee?
'Tis by thy ſecret, ſtrong attractive force,
As with a chain indiſſoluble bound,
Thy ſyſtem rolls entire: from the far bourne
Of utmoſt *Herſchel,* wheeling wide his round
Of *fourſcore* years; to Mercury, whoſe diſk
Can ſcarce be caught by philoſophic eye,
Loſt in the near effulgence of thy blaze.

Charles. You have ſubſtituted the words Herſchel, and fourſcore, for Saturn and thirty. Theſe lines are deſcriptive of the figure.

James. For what are the ſmaller circles which are attached to ſeveral of the larger ones intended?

Tutor. They are intended to repreſent the *orbits* of the ſeveral ſatellites or moons belonging to ſome of the planets.

James. What do you mean by the word orbit?

Tutor. The path deſcribed by a planet in its courſe round the ſun, or by a moon round its primary planet, is called its *orbit.* Look to the orbit of the earth in *t* (Fig. 2.) and you will ſee a little circle, which repreſents the orbit in which our moon performs its monthly journey.

Charles. Has neither *Mercury* nor *Venus* any moon?

Tutor. None have ever been diſcovered belonging either to Mercury, Venus, or Mars. Jupiter, as you obſerve by the figure, has four moons: Saturn has ſeven: and the Herſchel planet, (which alſo goes by the name of the Georgium Sidus) has ſix, which for want of room are not drawn in the plate.

Charles. The *Solar Syſtem* then conſiſts of the ſun as a center, round which revolve *ſeven* planets, and *eighteen* ſatellites or moons. Are there no other bodies belonging to it?

Tutor. Yes, two other planetary bodies have been very lately diſcovered as belonging to the ſolar ſyſtem. Theſe are very ſmall and called the Piazzi and Olbers, from the gentlemen who diſcovered them. There are comets alſo which make their appearance occaſionally; and it would be wrong poſitively to affirm, that there can be no other planets belonging to the Solar Syſtem; ſince, beſides the two bodies juſt mentioned, it is only within theſe few years that the ſeventh or the Herſchel has been known to exiſt as a planet connected with this ſyſtem.

Charles. Who firſt adopted the ſyſtem of the world which you have been deſcribing?

Tutor. It was conceived and taught by Pythagoras to his diſciples, 500 years before the time of Chriſt. But it ſeems ſoon to have been diſregarded, or perhaps totally rejected, till about 300 years ago, when it was revived by Copernicus, and is at length generally adopted by men of ſcience:

The ſun revolving on his axis turns,
And with creative fire intenſely burns;
Impell'd the forcive air, our earth ſupreme
Rolls with the planets round the ſolar gleam:
Firſt mercury completes his tranſient year,
Glowing refulgent, with reflected glare;
Bright Venus occupies a wider way,
The early harbinger of night and day;
More diſtant ſtill our globe terraqueous turns,
Nor chills intenſe, nor fiercely heated burns,
Around her rolls the lunar orb of light,
Trailing her ſilver glories thro' the night:
Beyond our globe the ſanguine Mars diſplays
A ſtrong reflection of primeval rays;
Next belted Jupiter far diſtant gleams,
Scarcely enlightened with the ſolar beams;
With four unfix'd receptacles of light
He towers majeſtic thro' the ſpacious height;
But farther yet the tardy Saturn lags,
And ſeven attendant luminaries drags;
Inveſting with a double ring his pace,
He circles thro' immenſity of ſpace.

CHATTERTON.

CONVERSATION VI.

Of the Figure of the Earth.

TUTOR. Having, in our last converſation, given you a deſcription of the Solar System in general, we will now proceed to conſider each of its parts ſeparately: and ſince we are moſt of all concerned with the *earth*, we will begin with that body.

James. You promiſed to give us ſome reaſons why this earth muſt be in the form of a globe and not a mere extended plane, as it appears to common obſervation.

Tutor. Suppoſe you were ſtanding by the ſea-ſhore, on a level with the water; and at a very conſiderable diſtance, as far as the eye can reach, you obſerve a ſhip approaching, what ought to be the appearance, ſuppoſing the ſurface of the ſea to be a flat plane?

Charles. We ſhould, I think, ſee the whole ſhip at once, that is the hull would be visible as ſoon as the top-maſt.

Tutor. It certainly muſt, or indeed rather ſooner, becauſe the body of the veſſel being ſo much larger than a ſlender maſt, it muſt neceſſarily be viſible at a greater diſtance.

James. Yes, I can ſee the ſteeple of a church at a much greater diſtance than I can diſcern the iron conductor which is upon it, and that I can perfectly ſee long before the little piece of gold wire, which is fixed at its extremity, is viſible.

Tutor. Well, but the top-maſt of a veſſel at ſea is always in view ſome little time before the hull of the veſſel can be diſcerned. Now, if the ſurface of the ſea be globular, this ought to be the appearance, becauſe the protuberance or ſwelling of the water between the veſſel, and the eye of the ſpectator, will hide the body of the ſhip ſome time after the pendant is ſeen above.

Charles. In the ſame way as if a high building, a church for inſtance, were ſituated on one ſide of a hill, and I was walking up on the oppoſite ſide, the ſteeple would come firſt in ſight, and as I advanced towards the ſummit, the other parts would come ſucceſſively in view.

Tutor. Your illuſtration is quite to the purpoſe: in the ſame way two perſons, walking up a hill on the oppoſite ſides, will perceive each other's heads firſt; and as they advance to the top, the other parts of their bodies will become viſible. With reſpect to the ſhip, the following figure will convey the idea very completely, (Plate 1. Fig. 3.) Suppoſe C A B repreſent a ſmall part of the curved ſurface of the ſea; if a ſpectator ſtand at B, while a ſhip is at C, only a ſmall part of the maſt is viſible to him, but as it advances, more of the ſhip is ſeen, till it arrive at *c*, when the whole will be in ſight:

Behold, when the glad ſhip ſhoots from the port:
Upon full ſail, the hulk firſt diſappears,
And then the lower, then the higher ſails;
At length the ſummit of the towering maſt
Alone is ſeen: nor leſs, when from the ſhip
The longing ſailor's eye in hope of ſhore:

For then, from the top-maſt, though more remote
Than either deck, the ſhore is firſt beheld.

LOFFT'S EUDOSIA.

Charles. When I ſtood by the ſea-ſide the water did *not* appear to me to be curved.

Tutor. Perhaps not; but its convexity may be diſcovered upon any ſtill water; as upon a river, which is extended a mile or two in length, for you might ſee a very ſmall boat at that diſtance while ſtanding upright; if then you ſtoop down ſo as to bring your eye near the water, you will find the ſurface of it riſing in ſuch a manner as to cover the boat, and intercept its view completely. Another proof of the globular figure of the earth is, that it is neceſſary for thoſe who are employed in cutting canals, to make a certain allowance for the convexity; ſince the true level is not a ſtraight line, but a curve which falls below it eight inches in every mile.

Charles. I have heard of people ſailing round the world, which is another proof, I imagine, of the globular figure of the earth.

Tutor. It is a well known fact that navigators have ſet out from a particular port, and by ſteering their courſe continually weſtward, have at length arrived at the ſame place from whence they firſt departed. Now had the earth been an extended plane, the longer they had travelled, the farther muſt they have been from home.

Charles. How is it known that they continued the ſame courſe? might they not have been driven round at open ſea?

Tutor. By means of the mariner's compaſs, the hiſtory, properties, and uſes of which, I will explain very particularly in a future part of our lectures, the method of ſailing on the ocean by one certain tract, is as ſure as travelling on the high London road from the metropolis to York. By this method, Ferdinand Magellan ſailed in the year 1519 from the weſtern coaſt of Spain, and continued his voyage in a weſtward courſe till he arrived after 1124 days in the ſame port from whence he ſet out. The ſame with reſpect to Great Britain, was done by our own countrymen Sir Francis Drake, Lord Anſon, Captain Cook, and many others.

Charles. Is then the common terreſtrial globe a juſt repreſentation of the earth?

Tutor. It is with this ſmall difference * that the artificial globe is a perfect ſphere, whereas the earth is a ſpheroid, that is, in the ſhape of an orange, the diameter from *pole to pole*, being about 37 miles ſhorter than that at the *Equator*.

James. What are the poles, Sir?

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* What the earth loſes of its ſphericity, by mountains and vallies, is very inconſiderable: the higheſt mountain bearing ſo little proportion to its bulk, as ſcarcely to be equivalent to the minuteſt protuberance on the ſurface of an orange:

These inequalities to us ſeem great;
But to an eye that comprehends the whole,
The tumour, which to us ſo monſtrous ſeems,
Is as a grain of ſparkling ſand that clings
To the ſmooth ſurface of a ſphere of glaſs;
Or as a fly upon the convex dome
Of a ſublime, ſtupendous edifice.

LOFFT.

Tutor. In the artificial globe (Plate 1. Fig. 4.) there is an axis NS about which it turns; now the two extremities or ends of this axis N and S are called the poles.

> The globe terreſtrial, with its ſlanting poles,
> And all its pond'rous load, unwearied rolls.
>
> BLACKMORE.

Charles. Is there any axis belonging to the earth?

Tutor. No; but as, we ſhall to-morrow ſhew, the earth turns round once in every 24 hours, ſo aſtronomers imagine an axis upon which it revolves as upon a center, the extremities of which imaginary axis are the poles of the earth, of theſe N the north pole points at all times exactly to *p*, the north pole of the heavens which we have already deſcribed (Plate 1, Fig. 1.) and which is, as you recollect, within two degrees of the polar ſtar.

James. And how do you define the *equator?*

Tutor. The *equator* AB (Plate 1. Fig. 4.) is the circumference of an imaginary circle paſſing through the center of the earth, perpendicular to the axis NS, and at equal diſtances from the poles.

Charles. And I think you told us, that if we conceived this circle extended every way to the fixed ſtars it would form the *celeſtial equator.*

Tutor: I did; it is alſo called the *equinoctial*, and you muſt not forget, that in this caſe it would cut the circle of the *ecliptic* CD in two points.

James. Why is the *ecliptic* marked, on the terreſtrial globe, ſince it is a circle peculiar to the heavens?

Tutor. Though the *ecliptic* be peculiar to the heavens, and the *equator* to the earth, yet they are both drawn on the terreſtrial and celeſtial globes, in order, among other things, to ſhew the poſition which theſe imaginary circles have to one another.

I ſhall now conclude our preſent converſation, with obſerving, that beſides the proofs adduced for the globular form of the earth, there are others equally concluſive, which will be better underſtood a few days hence.

CONVERSATION VII.

Of the diurnal Motion of the Earth.

TUTOR. Well, gentlemen, are you ſatisfied that the earth on which you tread is a globular body and not a mere extended plane?

Charles. Admitting the facts which you mentioned yeſterday, viz. that the top-maſt of a ſhip at ſea is always viſible before the body of the veſſel comes into ſight;—that navigators have repeatedly, by keeping the ſame direction ſailed round the world;—and that perſons employed in digging canals, can only execute their work with effect, by allowing for the ſuppoſed globular ſhape of the earth, it is evident the earth cannot be a mere extended plane.

James. But all theſe facts can be accounted for, upon the ſuppoſition that the earth is a globe, and therefore you conclude it is a globe: this was, I believe, the nature of the proof?

Tutor. It was: let us now advance one ſtep farther, and ſhew you that this globe turns on an imaginary axis every twenty-four hours; and thereby cauſes the ſucceſſion of day and night:

> And earth ſelf-balanc'd on her center hung.
>
> PAR. LOST.

James. I ſhall wonder if you are able to afford ſuch ſatisfactory evidence of the daily motion of the earth, as of its globular form.

Tutor. I truſt, nevertheleſs, that the arguments on this ſubject will be ſufficiently convincing, and that before we part you will admit, that the apparent motion of the ſun and ſtars is occaſioned by the diurnal motion of the earth.

Charles. I ſhall be glad to hear how this can be proved; for if, in the morning, I look at the ſun when riſing, it appears in the eaſt, at noon it has travelled to the ſouth, and in the evening I ſee it ſet in the weſtern part of the heavens.

James. Yes, and we obſerved the ſame laſt night (March the firſt) with reſpect to *Arcturus*, for about eight o'clock it had juſt riſen in the north-weſt part of the heavens, and when we went to bed two hours after, it had aſcended a good height in the heavens, evidently travelling towards the weſt.

Tutor. It cannot be denied that the heavenly bodies appear to riſe in the eaſt and ſet in the weſt; but the *appearance* will be the *ſame* to us, whether thoſe bodies revolve about the earth while that stands ſtill, or they stand ſtill while the earth turns on its axis the contrary way.

Charles. Will you explain this, Sir?

Tutor. Suppoſe GRCB (Plate II. Fig. 5.) to repreſent the earth, T the centre on which it turns from weſt to eaſt, according to the order of the letters GRCB. If a ſpectator on the ſurface of the earth at R, ſee a ſtar at H, it will appear to him to have juſt riſen; if now the earth be ſuppoſed to turn on its axis a fourth part of a revolution, the ſpectator will be carried from R to C, and the ſtar will be juſt over his head; when another fourth part of the revolution is completed the ſpectator will be at B, and to him the ſtar at H will be ſetting, and will not be viſible again till he arrive, by the rotation of the earth, at the ſtation R.

Charles. To the ſpectator, then, at R the appearance would be the ſame whether he turned with the earth into the ſituation B, or the ſtar at H had deſcribed, in a contrary direction, the ſpace HZO in the ſame time.

Tutor. It certainly would.

James. But if the earth really turned on its axis, ſhould we not perceive the motion?

Tutor. The earth in its diurnal rotation being ſubject to no impediments by reſiſting obſtacles, its motion cannot affect the ſenſes. In the ſame way ſhips on a ſmooth ſea are frequently turned entirely round by the tide, without the knowledge of thoſe perſons who happen to be buſy in the cabin or between the decks.

Charles. That is, becauſe they pay no attention to any other object but the veſſel in which they are, every part of which moves with themſelves.

James. But if while the ſhip is turning, without their knowlege, they happen to be looking at fixed diſtant objects, what will be the appearance?

Tutor. To them, thoſe objects which are at reſt will appear to be turning round the contrary way. In the ſame manner we are deceived in the motion of the earth round its axis, for if we attend to nothing but what is connected with the earth, we cannot perceive a motion of which we partake ourſelves, and if we fix our eyes on the heavenly bodies, the motion of the earth being ſo eaſy, they will appear to be turning in a direction contrary to the real motion of the earth.

Charles. I have ſome times ſeen a ſky-lark hovering and ſinging over a particular field for ſeveral minutes together, now if the earth is continually in motion while the bird remains in the ſame part of the air, why do we not ſee the field, over which he firſt aſcended, paſs from under him?

Tutor. Becauſe the atmoſphere, in which the lark is ſuſpended, is connected with the earth; partakes of its motion; and carries the lark along with it, and therefore independently of the motion given to the bird by the exertion of its wings, it has another in common with the earth, yourſelf, and all things on it, and being common to us all, we have no methods of aſcertaining it by means of the ſenſes. The rotation of the earth on its axis, the ſmoothneſs of its motion, and its effect on the atmoſphere are deſcribed by Milton in three lines:

——— That ſpinning ſleeps
On her ſoft axle as ſhe paces even,
And bears us ſwift with the ſmooth air along.

James. Though the motion of a ſhip cannot be obſerved without objects at reſt to compare with it, yet I cannot help thinking that if the earth moved we ſhould be able to diſcover it by means of the ſtars if they are fixed.

Tutor. Do you not remember once ſailing very ſwiftly on the river, when you told me that you thought all the trees, houſes, &c. on its banks were in motion?

James. I now recollect it well, and I had ſome difficulty in perſuading myſelf that it was not ſo.

Charles. This brings to my mind a ſtill ſtronger deception of this sort: when travelling with great ſpeed in a poſt-chaiſe, I ſuddenly waked from a ſleep in a ſmooth but narrow road, and I could ſcarcely help thinking, for ſeveral minutes, but that the trees and hedges were running away from us, and not we from them.

Tutor. I will mention another curious inſtance of this kind; if you ever happen to travel pretty ſwiftly in a carriage by the ſide of a field ploughed into long narrow ridges, and perpendicular to the road, you will think that all the ridges are turning round in a direction contrary to that of the carriage. Theſe facts may ſatisfy you that the appearances will be preciſely the ſame to us, whether the earth turn on its axis from weſt to eaſt, or the ſun and ſtars move from eaſt to weſt.

James. They will: but which is the more natural concluſion?

Tutor. This you ſhall determine for yourſelf. If the earth (Plate I.

Fig. 4.) turns on its axis in 24 hours, at what rate will any part of the equator AB move?

Charles. To determine this we muſt find the meaſure of its circumference, and then dividing this by 24, we ſhall get the number of miles paſſed through in an hour.

Tutor. Juſt ſo: now call the ſemi-diameter of the earth 4000 miles, which is rather more than the true meaſure.

James. Multiplying this by ſix* will give 24,000 miles for the circumſerence of the earth at the equator, and this divided by 24, gives 1000 miles for the ſpace paſſed through in an hour.

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* If the reader would be accurate in his calculations, he muſt take the mean radius of the earth at 3965 miles, and this multiplied by 6,28318 will give 24,912 miles for the circumference. Through the remainder of this work, the decimals in multiplication are omitted, in order that the mind may not be burdened with

Tutor. You are right. The ſun, I have already told you, is 95 millions of miles diſtant from the earth, tell me therefore, Charles, at what rate that body muſt travel to go round the earth in 24 hours?

Charles. I will; 95 millions multiplied by ſix will give 750 millions of miles for the length of his circuit, this divided by 24 gives nearly 24 millions of miles for the

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odd numbers. It ſeemed neceſſary, however, in this place to give the true ſemi-diameter of the earth, and the number (accurate to five places of decimals) by which if the radius of any circle be multiplied, the circumference is obtained.

ſpace he muſt travel in an hour, to go round the earth in a day.

Tutor. Which now is the more probable concluſion, either that the earth ſhould have a diurnal motion on its axis of 1000 miles in an hour, or that the ſun, which is a million of times larger than the earth, ſhould travel 24 millions of miles in the ſame time?

James. It is certainly more rational to conclude that the earth turns on its axis, the effect of which you told us was the alternate ſucceſſion of day and night.

Tutor. I did, and on this and ſome other topics we will enlarge to-morrow.

CONVERSATION VIII.

Of Day and Night.

JAMES. You are now, Sir, to apply the rotation of the earth about its axis to the ſucceſſion of day and night.

Tutor. I will, and for this purpoſe, ſuppoſe G R C B (Plate 11. Fig. 5.) to be the earth, revolving on its axis, according to the order of the letters that is from G to R; R to C, &c. If the ſun be fixed in the heavens at Z, and a line H O be drawn through the center of the earth T, it will repreſent that circle, which when extended to the heavens is called the *rational horizon.*

Charles. In what does this differ from the *ſenſible horizon?*

Tutor. The *ſenſible horizon* is that circle in the heavens which bounds the ſpectator's view, and which is greater or leſs, according as he ſtands higher or lower. For example; an eye placed at *five* feet above the ſurface of the earth or ſea, ſees 2 ¾ miles every way: but if it be at 20 feet high, that is 4 times the height, it will ſee 5½ miles, or twice the diſtance.*

Charles. Then the *ſenſible* differs from the *rational* horizon in this, that the *former* is ſeen from the ſurface of the earth, and the *latter* is ſuppoſed to be viewed from its center.

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* See Dr. Aſhworth's Trigonometry, Prop. 31. 2d Edition, 1803.

Tutor. You are right; and the riſing and ſetting of the ſun and ſtars are always referred to the rational horizon.

James. Why ſo? they appear to riſe and ſet as ſoon as they get above, or ſink below that boundary which ſeparates the viſible from the inviſible part of the heavens.

Tutor. They do not, however: and the reaſon is this, that the diſtance of the ſun and fixed ſtars is ſo great in compariſon of 4000 miles, (the difference between the ſurface and center of the earth) that it can ſcarcely be taken into account.

Charles. But 4000 miles ſeem to me an immenſe ſpace.

Tutor. Conſidered ſeparately, they are ſo, but when compared with 95 millions of miles, the diſtance of the ſun from the earth, they almoſt vaniſh as nothing.

James. But do the riſing and ſetting of the moon, which is at the diſtance of 240 thouſand miles only, reſpect alſo the rational horizon?

Tutor. Certainly; for 4000 compared with 240 thouſand, bear only the proportion of 1 to 60. Now if two ſpaces were marked out on the earth in different directions, the one 60 and the other 61 yards, ſhould you at once be able to diſtinguiſh the greater from the leſs?

Charles. I think not.

Tutor. Juſt in the ſame manner does the diſtance of the center from the ſurface of the earth vaniſh in compariſon of its diſtance from the moon.

James. We muſt not, however, forget the ſucceſſion of day and night.

Tutor. Well then; if the ſun be ſuppoſed at Z, it will illuminate by its rays, all that part of the earth that is above the horizon H O: to the inhabitants at G, its weſtern boundary, it will appear juſt riſing; to thoſe ſituated at R, it will be noon; and to thoſe in the eaſtern part of the horizon C, it will be ſetting.

Charles. I ſee clearly why it ſhould be noon to thoſe who live at R, becauſe the ſun is juſt over their heads, but it is not ſo evident, why the ſun muſt appear riſing and ſetting to thoſe who are at G and C.

Tutor. You are ſatisfied that a ſpectator cannot, from any place, obſerve more than a ſemi-circle of the heavens at any one time; now what part of the heavens will the ſpectator at G obſerve?

James. He will ſee the concave hemiſphere Z O N.

Tutor. The boundary to his view will be N and Z, will it not?

Charles. Yes; and conſequently the ſun at Z, will to him be juſt coming into ſight.

Tutor. Then by the rotation of the earth, the ſpectator at G will in a few hours come to R, when, to him, it will be noon; and thoſe who live at R, will have deſcended to C; now what part of the heavens will they ſee in this ſituation?

James. The concave hemiſphere X H Z, and Z being the boundary of their view one way, the ſun will to them be ſetting.

Tutor. Juſt ſo. After which they will be turned away from the ſun, and conſequently it will be night to them till they come again to G. Thus, by this ſimple motion of the earth on its axis, every part of it is, by turns, enlightened and warmed by the chearing beams of the ſun.

Charles. Does this motion of the earth account alſo for the apparent motion of the fixed ſtars?

Tutor. It is owing to the revolution of the earth round its axis, that we imagine the whole ſtarry firmament revolves about the earth in 24 hours.

James. If the heavens appear to turn on an axis, muſt there not be two points, namely, the extremities of that imaginary axis, which always keep their poſition?

Tutor. Yes, we muſt be underſtood to except the two celeſtial poles which are oppoſite to the poles of the earth, conſequently each fixed ſtar appears to deſcribe a greater or a leſs circle round theſe, according as it is more or leſs remote from thoſe celeſtial poles.

Charles. When we turn from that hemiſphere in which the ſun is placed, we immediately gain ſight of the other in which the ſtars are ſituated.

Tutor. Every part of the heaven is decorated with theſe glorious bodies: and,

Night opes the noblest ſcenes, and ſheds an
awe,
Which gives thoſe venerable ſcenes full weight,
And deep reception in th' intender'd heart.
This gorgeous apparatus! This diſplay!
This oſtentation of creative power!
This theatre! what eye can take it in?
By what divine enchantment was it rais'd
For minds of the firſt magnitude to launch
In endleſs ſpeculation, and adore?
One ſun by day, by night ten thouſand ſhine;
And light us deep into the Deity;
And boundleſs in magnificence and in might!

YOUNG.

James. If every part of the heavens be thus adorned, why do we not ſee the stars in the day as well as the night?

Tutor. Becauſe in the day time, the ſun's rays are ſo powerful, as to render *thoſe* coming from the fixed ſtars inviſible. But if you ever happen to go down into any very deep mine, or coal-pit, where the rays of the ſun cannot reach the eye, and it be a clear day, you may by looking up to the heavens, ſee the ſtars at noon as well as in the night.

Charles. If the earth always revolve on its axis in 24 hours, why does the length of the days and nights differ in different ſeaſons of the year?

Tutor. This depends on other cauſes connected with the earth's *annual* journey round the ſun, upon which we will converſe the next time we meet.

CONVERSATION IX.

Of the Annual Motion of the Earth.

TUTOR. Beſides the *diurnal* motion of the earth, by which the ſucceſſion of day and night is produced; it has another, called its *annual* motion, which is the journey it performs round the ſun in 365 days, 5 hours, 48 minutes, and 49 ſeconds.

Charles. Are the different ſeaſons to be accounted for by this motion of the earth?

Tutor. Yes, it is the cauſe of the different lengths of the days and nights, and conſequently of the different ſeaſons, viz. *Spring*, *Summer*, *Autumn*, and *Winter* :

It ſhifts the ſeaſons, months, and days,
The ſhort-lived offspring of revolving time;
By turns they die, by turns are born.
Now cheerful Spring the circle leads
And ſtrews with flowers the ſmiling meads;
Gay Summer next, whom ruſſet robes adorn,
And waving fields of yellow corn;
Then Autumn, who with laviſh ſtores the lap of
Nature ſpreads;
Decrepit Winter, laggard in the dance,
(Like feeble age oppreſt with pain)
A heavy ſeaſon does maintain,
With driving ſnows and winds and rain;
Till Spring, recruited to advance,
The various year rolls round again.

HUGHES.

James. How is it known that the earth makes this annual journey round the ſun?

Tutor. I told you yeſterday, that through the ſhaft of a very deep mine, the ſtars are viſible in the day as well as in the night; they are alſo viſible in the day time, by means of a teleſcope properly fitted up for the purpoſe; by this method, the ſun and ſtars are viſible at the ſame time. Now if the ſun be ſeen in a line with a fixed ſtar, to-day at any particular hour, it will, in a few weeks, by the motion of the earth, be found conſiderably to the eaſt of him: and if the obſervations be continued through the year, we ſhall be able to trace him round the heavens to the ſame fixed ſtar from which we ſet out; conſequently, the ſun muſt have made a journey round the earth in that time, or the earth round him.

Charles. And the ſun being a

million of times larger than the earth, you will ſay that it is more natural, that the smaller body ſhould go round the larger, than the reverſe.

Tutor. That is a proper argument; but it may be ſtated in a much ſtronger manner. The ſun and earth mutually attract one another, and ſince they are in equilibrio by this attraction, you know, their momenta muſt be equal*, therefore the earth being the ſmaller body, muſt make out by its motion what is wants in the quantity of its matter, and of courſe, it muſt be that which performs the journey.

James. But if you refer to the principle of the lever, to explain the mutual attraction of the ſun and earth, it is evident, that both bodies muſt turn round ſome point as a common center.

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* See Vol. I. Converſation XIV. p. 121.

Tutor. They do; and that is the common center of gravity of the two bodies. Now this point between the earth and ſun is within the ſurface of the latter body.

Charles. I underſtand how this is; becauſe the center of gravity between any two bodies, muſt be as much nearer to the center of the larger body than the ſmaller, as the former contains a greater quantity of matter than the latter.

Tutor. You are right: but you will not conclude that, becauſe the ſun is a million of times larger than the earth, therefore, it contains a quantity of matter, a million of times greater than that contained in the earth.

James. Is it then known, that the earth is compoſed of matter more denſe than that which compoſes the body of the ſun?

Tutor. The earth is compoſed of matter four times denſer than that of the ſun; and hence the quantity of matter in the ſun, is between two and three hundred thouſand times greater than that which is contained in the earth.

Charles. Then for the momenta of theſe two bodies to be equal, the velocity of the earth muſt be between two and three hundred thouſand times greater than that of the ſun.

Tutor. It muſt: and to effect this, the center of gravity between the ſun and earth, muſt be as much nearer to the center of the ſun, than it is to the center of the earth, as the former body contains a greater quantity of matter than the latter: and hence it is found to be ſeveral thouſand miles within the ſurface of the ſun.

James. I now clearly perceive, that ſince one of theſe bodies revolves about the other in the ſpace of a year, and that they both move round their common center of gravity, that it muſt, of neceſſity, be the earth which revolves about the ſun, and not the ſun round the earth.

Tutor. Your inference is juſt. To ſuppoſe that the ſun moves round the earth, is as abſurd as to maintain, that a mill-ſtone could be made to move round a pebble.

CONVERSATION X.

Of the Seaſons.

TUTOR. I will now ſhew you how the different ſeaſons are produced by the annual motion of the earth.

James. Upon what do they depend, Sir?

Tutor. The variety of the ſeaſons depends (1) upon the length of the days and nights; and, (2) upon the poſition of the earth with reſpect to the ſun.

Charles. But if the earth turn round its imaginary axis every 24 hours, ought it not to enjoy equal days and nights all the year?

Tutor. This would be the caſe if the axis of the earth NS (Plate II Fig. 6) were perpendicular to a line CE drawn through the centers of the ſun and earth; for then as the ſun always enlightens one half of the earth by its rays, and as it is day at any given place on the globe, ſo long as that place continues in the enlightened hemiſphere, every part, except the two poles, muſt during its rotation on its axis, be one half of its time in the light and the other half in darkneſs: or, in other words, the days and nights would be equal to all the inhabitants of the earth, excepting to thoſe, if any, who live at the poles.

James. Why do you except the people at the poles?

Tutor. Becauſe the view of the ſpectator ſituated at the poles N and S, muſt be bounded by the line C E, conſequently to him the ſun would never appear to riſe, or ſet, but would always be in the horizon.

Charles. If the earth were thus ſituated, would the rays of the ſun always fall vertically to the ſame part of it?

Tutor. They would: and that part would be E Q the equator, and, as we ſhall preſently ſhew, the heat excited by the ſun being greater or leſs in proportion as its rays come more or leſs perpendicularly upon any body, the parts of the earth about the equator would be ſcorched up, while thoſe between 40 and 50 degrees on each ſide of that line and the poles, would be deſolated by an unceaſing winter:

> ——— ſome ſay the ſun
> Was bid turn reins from th' *equinoctial* road
> Up to the *Tropic Crab*; thence down amain
> By *Leo*, and the *Virgin*, and the *Scales*
> As deep as *Capricorn*, to bring in change
> Of ſeaſons to each clime: elſe had the ſpring
> Perpetual ſmil'd on earth with vernant flowers,
> Equal in days and nights, except to thoſe
> Beyond the *polar* circles: to them day
> Had unbenighted ſhone, while the low ſun
> To recompence his diſtance, in their ſight
> Had rounded ſtill th' horizon.
>
> PAR. LOST, Book x. l. 672.

James. In what manner is this prevented?

Tutor. By the axis of the earth NS (Plate II. Fig. 7.) being inclined or bent about 23 degrees and a half out of the perpendicular as it is deſcribed by Milton:

> ——— He bid his angels turn aſkance
> The poles of earth twice ten degrees and more
> From the ſun's axle.

In this caſe you obſerve, that all the parallel circles, except the equator, are divided into two unequal parts, having a greater or leſs portion of their circumferences in the enlightened, than in the dark hemiſphere, according to their ſituation with reſpect to N the north, or S the ſouth pole.

Charles. At what ſeaſon of the year is the earth repreſented in this figure?

Tutor. At our ſummer ſeaſon: for you obſerve that the parallel circles in the northern hemiſphere have their greater parts enlightened and their ſmaller parts in the dark. If DL repreſent that circle of latitude on the globe in which Great Britain is ſituated, it is evident that about two thirds of it is in the light and only one third in darkneſs.

You will remember that *parallels of latitude* are circles on the ſurface of the earth, or its repreſentative the terreſtrial globe, drawn parallel to the equator.

James. Is that the reaſon why our days towards the middle of June are 16 hours long, and the nights but eight hours?

Tutor. It is: and if you look to the parallel next beyond that marked DL, you will ſee a ſtill greater diſproportion between the day and night, and the parallel more north than this is entirely in the light.

Charles. Is it then all day there?

Tutor. To the whole ſpace between that and the pole it is continual day for ſome time, the duration of which is in proportion to its vicinity to the pole; and at the pole there is a permanent day-light for ſix months together.

James. And during that time it muſt I ſuppoſe be night to the people who live at the ſouth-pole?

Tutor. Yes, the figure ſhews that the ſouth-pole is in darkneſs; and you may obſerve, that to the inhabitants living in equal parallels of latitude, the one north, and the other ſouth, the length of the days to the one will be always equal to the length of the nights to the other.

Charles. What then ſhall we ſay to thoſe who live at the equator, and conſequently have no latitude?

Tutor. To them the days and nights are *always* equal, and of courſe twelve hours each in length, and this is alſo evident from the figure, for in every poſition of the globe one half of the equator is in the light and the other half in darkneſs.

James. If, then, the length of the days is the cauſe of the different ſeaſons, there can be no variety in this reſpect, to thoſe who live at the equator.

Tutor. You ſeem to forget that the change in the ſeaſons depends upon the poſition of the earth with reſpect to the ſun, that is upon the *perpendicularity* with which the rays of light fall upon any particular part of the earth; as well as upon the length of the days.

Charles. Does this make any material difference with regard to the heat of the ſun?

Tutor. It does: let AB (Plate II. Fig. 8.) repreſent a portion of the earth's ſurface, on which the ſun's rays fall perpendicularly; let BC repreſent an equal portion on which they fall obliquely or aſlant. It is manifeſt that BC, though it be equal to AB, receives but half the light and heat, that AB does. Moreover by the ſun's rays coming more perpendicularly, they come with greater force, as well as in greater numbers, on the ſame place.

CONVERSATION XI.

Of the Seaſons.

TUTOR. Let us now take a view of the earth in its annual courſe round the ſun, conſidering its axis as inclined 23½ degrees to a line perpendicular to its orbit, and keeping, through its whole journey, a direction parallel to itſelf; and you will find, that according as the earth is in different parts of its orbit, the rays of the ſun are preſented perpendicularly to the equator, and to every point of the globe, within 23½ degrees of it both north and ſouth.

This figure (Plate II. Fig 9.) repreſents the earth in four different parts of its orbit, or as it is ſituated with reſpect to the ſun in the months of March, June, September, and December.

Charles. The earth's orbit is not made circular in the figure.

Tutor. It is nearly circular, but you are ſuppoſed to view it from the ſide B D, and therefore, though almoſt a circle, it appears to be a long ellipſe. All circles appear elliptical in an oblique view, as is evident, by looking obliquely at the rim of a baſon, at ſome diſtance from you. For the true figure of a circle can only be ſeen when the eye is directly over its center. You obſerve that the ſun is not in the center.

James. I do; and it appears nearer to the earth in the winter than in the ſummer.

Tutor. We are indeed more than three millions of miles nearer to the ſun in December than we are in June.

Charles. Is this poſſible, and yet our winter is ſo much colder than the ſummer?

Tutor. Notwithſtanding this, it is a well known fact. For it is aſcertained, that our ſummer, that is, the time that paſſes between the vernal and autumnal equinoxes, is nearly eight days longer than our winter, or the time between the autumnal and vernal equinoxes. Conſequently the motion of the earth is ſlower in the former caſe than in the latter, and therefore, as we ſhall ſee, it muſt be at a greater diſtance from the ſun. Again, the ſun's *apparent* diameter is greater in our winter than in ſummer, but the apparent diameter of any object increaſes in proportion as our diſtance from the object is diminiſhed, and therefore we conclude, that we are nearer the ſun in winter than in ſummer. The ſun's apparent diameter in winter is 32′..47″; in ſummer 31′..40″.

James. But if the earth is farther from the ſun in ſummer than in winter, why are our winters ſo much colder than our ſummers?

Tutor. Becauſe firſt, in the ſummer, the ſun riſes to a much greater height above our horizon, and therefore its rays coming more perpendicularly, more of them, as we ſhewed you yeſterday, muſt fall upon the ſurface of the earth, and come alſo with greater force, which is the principal cauſe of our greater ſummer's heat. Secondly, In the ſummer, the days are very long, and the nights ſhort; therefore the earth and air are heated by the ſun in the day, more than they are cooled in the night.

James. Why have we not, then, the greateſt heat at the time when the days are longeſt?

Tutor. The hotteſt ſeaſon of the year is certainly a month or two after this, which may be thus accounted for. A body once heated does not grow cold again inſtantaneouſly, but gradually: now, as long as more heat comes from the ſun in the day, than is loſt in the night, the heat of the earth and air will be daily increaſing, and this muſt evidently be the caſe for ſome weeks after the longeſt day, both on account of the number of rays which fall on a given ſpace, and alſo from the perpendicular direction of thoſe rays.

James. Will you now explain to us in what manner the ſeaſons are produced?

Tutor. By referring to the figure (Plate II. Fig. 9.) you will obſerve, that in the month of June, the north-pole of the earth inclines towards the ſun, and conſequently brings all the northern parts of the globe more into light, than at any other time in the year.

Charles. Then to the people in thoſe parts it is ſummer.

Tutor. It is: but in December, when the earth is in the oppoſite part of its orbit, the north-pole declines from the ſun, which occaſions the northern places to be more in the dark than in the light: and the reverſe at the ſouthern places.

James. Is it then ſummer to the inhabitants of the ſouthern hemiſphere?

Tutor. Yes, it is; and winter to us. In the months of March and September, the axis of the earth does not incline to, nor decline from, the ſun, but is perpendicular to a line drawn from its center. And then the poles are in the boundary of light and darkneſs, and the ſun being directly vertical to, or over the equator, makes equal day and night at all places. Now trace the annual motion of the earth in its orbit for yourſelf, as it is repreſented in the figure.

Charles. I will, Sir! About the 20th of March the earth is in Libra, and conſequently to its inhabitants the ſun will appear in Aries, and be vertical to the equator.

Tutor. And then the equator, and all its parallels, are equally divided between the light and dark.

Charles. Conſequently the days and nights are equal all over the world. As the earth purſues its journey from March to June its northern hemiſphere comes more into light, and on the 21ſt of that month, the ſun is vertical to the tropic of Cancer.

Tutor. And you then obſerve, that all the circles parallel to the equator are unequally divided; thoſe in the northern half have their greater parts in the light, and thoſe in the ſouthern half have their larger parts in darkneſs.

Charles. Yes; and of courſe it is ſummer to the inhabitants of the northern hemiſphere, and winter to the ſouthern.

I now trace it to September, when I find the ſun vertical again to the equator, and of courſe, the days and nights are again equal. And following the earth in its journey to December, or when it has arrived at Cancer, the ſun appears in Capricorn; and is vertical to that part of the earth called the tropic of Capricorn, and now the ſouthern pole is enlightened, and all the circles on that hemiſphere have their larger parts in light, and, of courſe, it is ſummer to thoſe parts, and winter to us in the northern hemiſphere.

Tutor. Can you, James, now tell me, why the days lengthen and ſhorten from the equator to the polar circles every year?

James. I will try to explain myſelf on the ſubject. Becauſe the ſun in March is vertical to the equator, and from that time to the 21ſt of June it becomes vertical ſucceſſively to all other parts of the earth between the equator and the tropic of Cancer, and in proportion as it becomes vertical to the more northern parts of the earth, it declines from the ſouthern, and conſequently, to the former the days lengthen, and to the latter they ſhorten. From June to September the ſun is again vertical ſucceſſively to all the ſame parts of the earth, but in a reverſe order.

Charles. Since it is ſummer to all thoſe parts of the earth, where the ſun is vertical, and we find that the ſun is vertical twice in the year to the equator, and every part of the globe between the equator and tropics; there muſt be alſo two ſummers in a year to all thoſe places.

Tutor. There are; and in thoſe parts near the equator, they have two harveſts every year.——But let your brother finiſh his deſcription.

James. From September to December, it is ſucceſſively vertical to all the parts of the earth ſituated between the equator and the tropic of Capricorn, which is alſo the cauſe of the lengthening of the days in the ſouthern hemiſphere, and of their becoming ſhorter in the northern.

Tutor. Can you, Charles, tell me why there is ſometimes no day or night for ſome little time together within the polar circles?

Charles. The ſun always ſhines upon the earth 90 degrees every way, and when he is vertical to the tropic of Cancer, which is 23½ degrees north of the equator, he muſt ſhine the ſame number of degrees beyond the pole, or to the polar circle, and while he thus ſhines, there can be no night to the people within that polar circle; and, of courſe, to the inhabitants at the ſouthern polar circle, there can be no day at the ſame time, for as the ſun's rays reach but 90 degrees every way, they cannot ſhine far enough to reach them.

Tutor. Tell me, now, why there is but one day and night in the whole year at the poles?

Charles. For the reaſon which I have juſt given, the ſun muſt ſhine beyond the north-pole all the time he is vertical to thoſe parts of the earth, ſituated between the equator and the tropic of Cancer, that is, from March the 21ſt to September the 20th, during which time there can be no night at the north pole, nor any day at the ſouth pole. The reverſe of this may be applied to the ſouthern pole.

James. I underſtand now, that the lengthening and ſhortening of the days, and different ſeaſons, are produced by the annual motion of the earth round the ſun; the axis of the earth, in all parts of its orbit, being kept parallel to itſelf. But if thus parallel to itſelf, how can it in all poſitions point to the pole-ſtar in the heavens?

Tutor. Becauſe the diameter of the earth's orbit A C is nothing in compariſon of the diſtance of the earth from the fixed ſtars. Suppoſe you draw two parallel lines at the diſtance of three or four yards from one another, will they not both point to the moon when ſhe is in the horizon?

James. Three or four yards cannot be accounted as any thing, in compariſon of 240 thouſand miles, the diſtance of the moon from us.

Tutor. Perhaps, three yards bear a greater proportion to 240 thouſand miles, than 190 millions of miles bear to our diſtance from the polar ſtar.

CONVERSATION XII.

Of the Equation of Time.

TUTOR. You are now, I preſume, acquainted with the motions peculiar to this globe on which we live?

Charles. Yes: it has a rotation on its axis from weſt to eaſt every 24 hours, by which day and night are produced, and alſo the apparent diurnal motion of the heavens from eaſt to weſt.

James. The other is its annual revolution in an orbit round the ſun, likewiſe from weſt to eaſt, at the diſtance of about 95 millions of miles from the ſun.

Tutor. You underſtand alſo, in what manner this annual motion of the earth, combined with the inclination of its axis, is the cauſe of the variety of ſeaſons.

We will therefore proceed to inveſtigate another curious ſubject, viz. the equation of time, and to explain to you the difference between *equal* and *apparent* time.

Charles. Will you tell us what you mean by the words *equal* and *apparent*, as applied to time?

Tutor. *Equal* time is meaſured by a clock, that is ſuppoſed to go without any variation, and to meaſure exactly 24 hours from noon to noon. And *apparent* time is meaſured by the *apparent* motion of the ſun in the heavens, or by a good ſun-dial.

Charles. And what do you mean, Sir, by the *equation of time?*

Tutor. It is the adjuſtment of the difference of time, as ſhewn by a well regulated clock and a true ſun-dial.

James. Upon what does this difference depend?

Tutor. It depends *firſt* upon the inclination of the earth's axis. And ſecondly upon the elliptic form of the earth's orbit; for, as we have already ſeen, the earth's orbit being an ellipſe, its motion is quicker when it is in *perihelion*, or neareſt to the ſun; and ſlower when it is in *aphelion*, or fartheſt from the ſun.

Charles. But I do not yet comprehend, what the rotation of the earth has to do with the going of a clock or watch.

Tutor. The rotation of the earth is the moſt equable and uniform motion in nature, and is completed in 23 hours, 56 minutes and 4 ſeconds; this ſpace of time is called a *ſidereal* day, becauſe any meridian on the earth will revolve from a fixed ſtar, to that ſtar again in this time. But a *ſolar* or natural day, which our clocks are intended to meaſure, is the time which any meridian on the earth will take in revolving from the ſun to the ſun again, which is about 24 hours, ſometimes a little more, but generally leſs.

James. What occaſions this difference between the ſolar and ſidereal day?

Tutor. The diſtance of the fixed ſtars is ſo great, that the diameter of the earth's orbit, though 190 millions of miles, when compared with it, is but a point, and therefore any meridian on the earth will revolve from a fixed ſtar to that ſtar again in exactly the ſame time, as if the earth had only a diurnal motion, and remained always in the ſame part of its orbit. But with reſpect to the ſun, as the earth advances almoſt a degree eaſtward in its orbit, in the ſame time that it turns eaſtward round its axis, it muſt make more than a complete rotation before it can come into the ſame poſition with the ſun that it had the day before. In the ſame way, as when both the hands of a watch or clock ſet off together at 12 o'clock, the minute-hand muſt travel more than a whole circle before it will overtake the hour-hand, that is, before they will be in the ſame relative poſition again. Thus the ſidereal days are ſhorter than the ſolar ones by about four minutes, as is evident from obſervation:

Watch with nice eye the earth's diurnal way
Marking her *ſolar* and *ſidereal* day;
Her ſlow nutation, and her varying clime,
And trace with mimic art the march of time.

BOTANICAL GARDEN.

Charles. Still I do not underſtand the reaſon why the clocks and dials do not agree.

Tutor. A good clock is intended to meaſure that equable and uniform time which the rotation of the earth on its axis exhibits. Whereas the dial meaſures time by the *apparent* motion of the ſun, which, as we have explained, is ſubject to variation. Or thus: though the earth's motion on its axis be perfectly uniform, and conſequently the rotation of the *equator*, the plane of which is perpendicular to the axis, or of any other circle parallel to it, be likewiſe equable, yet we meaſure the length of the natural day by means of the ſun, whoſe *apparent* annual motion is not in the equator, or any of its parallels, but in the ecliptic, which is oblique to it.

James. Do you mean by this, that the equator of the earth, in its annual journey, is not always directed towards the center of the ſun?

Tutor. I do: twice only in the year, a line drawn from the center of the ſun to that of the earth paſſes through thoſe points where the equator and ecliptic croſs one another; at all other times, it paſſes through ſome other part of that oblique circle, which is repreſented on the globe by the ecliptic line. Now when it paſſes through the equator or the tropics, which are circles parallel to the equator, the ſun and clocks go together as far as regards this cauſe, but at other times they differ, becauſe *equal* portions of the ecliptic paſs over the meridian in *unequal* parts of time on account of its obliquity.

Charles. Can you explain this by a figure?

Tutor. It is eaſily ſhewn by the globe which this figure ♈ N ♎ S (Plate II. Fig. 10.) may repreſent; ♈ ♎ will be the equator, ♈ ♋ ♎ the northern half of the ecliptic, and ♈ ♑ ♎ the ſouthern half. Make chalk or pencil marks *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, all round the *equator* and *ecliptic*, at equal diſtances (ſuppoſe 20 degrees) from each other beginning at Aries. Now by turning the globe on its axis, you will perceive that all the marks in the firſt quadrant of the *ecliptic*, that is, from Aries to Cancer, come *ſooner* to the brazen meridian than their correſponding marks on the *equator*:—thoſe from the beginning of Cancer to Libra come *later*:—thoſe from Libra to Capricorn ſooner:—and thoſe from Capricorn to Aries later.

Now time as meaſured by the ſun-dial is repreſented by the marks on the *ecliptic*; that meaſured by a good clock by thoſe on the *equator*.

Charles. Then while the ſun is in the firſt and third quarters, or what is the ſame thing, while the earth is travelling through the ſecond and fourth quarters, that is, from Cancer to Libra, and from Capricorn to Aries, the ſun is faſter than the clocks, and while it is travelling the other two quarters it is ſlower.

Tutor. Juſt ſo: becauſe while the earth is travelling through the ſecond and fourth quadrants, equal portions of the ecliptic come *ſooner* to the meridian than their correſponding parts of the equator: and during its journey through the firſt and third quadrants, the equal parts of the ecliptic arrive *later* at the meridian than their correſponding parts of the equator.

James. If I underſtand what you have been ſaying, the dial and clocks ought to agree at the equinoxes, that is, on the 20th of March, and the 23d of September, but if I refer to the Ephemeris, I find that on the former day (1803) the clock is nearly 8 minutes before the ſun: and on the latter day the clock is more than 7 minutes behind the ſun.

Tutor. If this difference between time meaſured by the dial and clock depended only on the inclination of the earth's axis to the plane of its orbit, the clocks and dial ought to be together at the equinoxes, and alſo on the 21ſt of June and the 21ſt of December, that is, at the ſummer and winter ſolſtices; becauſe, on thoſe days, the *apparent* revolution of the ſun is parallel to the equator. But I told you there was another cauſe why this difference ſubſiſted.

Charles. You did: and that was the elliptic form of the earth's orbit.

Tutor. If the earth's motion in its orbit were uniform, which it would be if the orbit were circular, then the whole difference between *equal* time as ſhewn by the clock, and *apparent* time as ſhewn by the ſun, would ariſe from the inclination of the earth's axis. But this is not the caſe, for the earth travels, when it is neareſt the ſun, that is, in the winter, more than a degree in 24 hours, and when it is fartheſt from the ſun, that is, in ſummer, leſs than a degree in the ſame time: conſequently from this cauſe the natural day would be of the greateſt length when the earth was neareſt the ſun, for it muſt continue turning the longeſt time after an entire rotation, in order to bring the meridian of any place to the ſun again: and the ſhorteſt day would be when the earth moves the ſloweſt in her orbit. Now theſe inequalities, combined with thoſe ariſing from the inclination of the earth's axis, make up that difference which is ſhewn by the equation table, found in the Ephemeris, between good clocks and true ſun-dials.

CONVERSATION XIII.

Of Leap-Year.

JAMES. Before we quit the ſubject of time, will you give us ſome account of what is called in our Almanacs Leap-Year?

Tutor. I will. The length of our year is, as you know, meaſured by the time which the earth takes in performing her journey round the ſun, in the ſame manner as the length of the day is meaſured by its rotation on its axis. Now, to compute the exact time taken by the earth in its annual journey, was a work of conſiderable difficulty. Julius Cæſar was the firſt perſon who ſeems to have attained to any accuracy on this ſubject.

Charles. Do you mean the firſt Roman Emperor, who landed alſo in Great-Britain?

Tutor. I do. He was not leſs celebrated as a man of ſcience, than he was renowned as a general: of him it was ſaid,

Amidſt the hurry of tumultuous war,
The ſtars, the gods, the heavens were ſtill his
care,
Nor did his ſkill to fix the rolling year
Inferior to Eudoxus' art appear.

Julius Cæſar, who was well acquainted with the learning of the Egyptians, fixed the length of the year to be 365 days and ſix hours, which made it ſix hours longer than the Egyptian year. Now, in order to allow for the odd 6 hours in each year, he introduced an additional day every fourth year, which accordingly conſiſts of 366 days, and is called *Leap*-Year, while the other three have only 365 days each. From him it was denominated the *Julian* year.

James. It is alſo called *Biſſextile* in the Almanacs, what does that mean?

Tutor. The Romans inſerted the intercalary day between the 23d and 24th of Febuary: and becauſe the 23d of Febuary, in their calendar, was called *ſexto calendas Martii*, the 6th of the calends of March; the intercalated day was called *bis ſexto calendas Martii*, the ſecond ſixth of the calends of March, and hence the year of intercalation had the appellation of *Biſſextile.* This day was choſen at Rome, on account of the expulſion of Tarquin from the throne, which happened on the 23d of February. We introduce, in Leap-Year, a new day in the ſame month, namely, the 29th.

Charles. Is there any rule for knowing what year is Leap-Year?

Tutor. It is known by dividing the date of the year by 4, if there be no remainder, it is Leap-Year; thus 1799 divided dy 4, leaves a remainder of 3, ſhewing that it is the 3d year after Leap-Year. Theſe two lines contain the rule:

Divide by 4; what's left ſhall be
For Leap-year 0; for paſt 1, 2, 3.

James. The year, however, does not conſiſt of 365 days and 6 hours, but of 365 days, 5 hours, 48 minutes, and 49 ſeconds*. Will not this occaſion ſome error?

Tutor. It will: and by ſubtracting the latter number from the former, you will find that the error amounts to 11 minutes and 11 ſeconds every year, or to a whole day in about 130 years: notwithſtanding this, the Julian year continued to be in general uſe till the year 1582, when Pope Gregory the 13th, undertook to rectify the error which, at that time, amounted to 10 days. He accordingly commanded the 10 days between the 4th and 15th of October in that year to be ſuppreſſed, ſo that the 5th day of that month was called the 15th. This alteration took place through the greater part of Europe, and the year was afterwards called the Gregorian-year, or *New Style*. In this country, the method of reckoning, according to the New Style, was not admitted into our calendars 'till the year 1752, when the error amounted to nearly 11 days, which were taken from the month of September, by calling the 3d of that month the 14th.

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* See Converſation IX.

Charles. By what means will this accuracy be maintained?

Tutor. The error amounting to one whole day in about 130 years, it is ſettled by an act of parliament, that the preſent year 1800 and the year 1900, which are, according to the rule juſt given, Leap-Years, ſhall be computed as common years, having only 365 days in each: and that every four hundredth year afterwards ſhould be common years alſo. If this method be adhered to, the preſent mode of reckoning will not vary a ſingle day from true time, in leſs than 5000 years.

By the ſame act of parliament, the legal beginning of the year was changed from the 25th of March to the 1ſt of January. So that the ſucceeding months of January, February, and March, up to the 24th day, which would, by the Old Style, have been reckoned part of the year 1752, were accounted as the three firſt months of the year 1753.

CONVERSATION XIV.

Of the Moon.

TUTOR. You are now, gentlemen, acquainted with the reaſons for the diviſion of time into days and years.

Charles. Theſe diviſions have their foundation in nature, the *former* depending upon the rotation of the earth on its axis; the *latter* upon its revolution in an elliptic orbit about the ſun as a center of motion.

James. Is there any natural reaſon for the diviſion of years into weeks, or of days into hours, minutes and ſeconds?

Tutor. Theſe diviſions were invented entirely for the convenience of mankind, and are accordingly different in different countries. There is, however, another diviſion of time marked out by nature.

Charles. What is that, Sir?

Tutor. The length of the *month*: not indeed that month which conſiſts of four weeks, nor that by which the year is divided into 12 parts. Theſe are both arbitrary. But by a month is meant the time which the moon takes in performing her journey round the earth:

Then mark'd aſtronomers with keener eyes
The moon's refulgent journey through the ſkies.
Darwin.

James. How many days does the moon take for this purpoſe?

Tutor. If you refer to the time in which the moon revolves from one point of the heavens to the ſame point again, it conſiſts of 27 days, 7 hours, and 43 minutes, this is called the *periodical* month: but if you refer to the time paſſed from new moon to new moon again, the month conſiſts of 29 days 12 hours and 44 minutes, this is called the *ſynodical* month.

Charles. Pray explain the reaſon of this difference.

Tutor. It is occaſioned by the earth's annual motion in its orbit. Let us refer to our watch as an example. The two hands are together at 12 o'clock; now when the minute-hand has made a complete revolution, are they together again?

James. No; for the hour-hand is advanced the twelfth part of its revolution, which in order that the other may overtake, it muſt travel five minutes more than the hour.

Tutor. And ſomething more, for the hour-hand does not wait at the figure 1 till the other comes up: and therefore they will not be together 'till between 5 and 6 minutes after one.

Now apply this to the earth and moon, ſuppoſe (Plate III. Fig. 11.) S to be the ſun; T the earth in a part of its orbit QL; and E to be the poſition of the moon: if the earth had no motion, the moon would move round its orbit EHC into the poſition E again, in 27 days, 7 hours, 43 minutes; but while the moon is deſcribing her journey, the earth has paſſed through nearly a twelfth part of its orbit, which the moon muſt alſo deſcribe before the two bodies come again into the ſame poſition that they before held with reſpect to the ſun: this takes up ſo much more time as to make her ſynodical month equal to 29 days, 12 hours, and 44 minutes: hence the foundation of the diviſion of time into months.

We will now proceed to deſcribe ſome other particulars relating to the moon, as a body depending, like the earth, on the ſun for her light and heat.

Charles. Does the moon ſhine with a borrowed light only?

Tutor. This is certain; for otherwiſe, if like the ſun, ſhe were a luminous body, ſhe would always ſhine with a full orb as the ſun does;

——————— Leſs bright the moon,
But oppoſite in level'd weſt was ſet,
His mirror, with full face *borrowing* her light
From him, for other light ſhe needed none.

Her diameter is nearly 2200 miles in length.

James. And I remember ſhe is at the diſtance of 240,000 miles from the earth.

Tutor. The ſun s (Plate III. Fig. 11.) always enlightens one half of the moon E, and its whole enlightened hemiſphere, or a part of it, or none at all, is seen by us according to her different poſitions in the orbit with reſpect to the earth, for only thoſe parts of the enlightened half of the moon are viſible at T which are cut off by, and are *within* the orbit.

James. Then when the moon is at E, no part of its enlightened ſide is viſible to the earth.

Tutor. You are right: it is then *new* moon, or *change*, for it is uſual to call it new moon the firſt day it is viſible to the earth, which is not 'till the ſecond day after the change. And the moon being in a line between the ſun and earth, they are ſaid to be in *conjunction.*

Charles. And at A all the illuminated hemiſphere is turned to the earth.

Tutor. This is called *full* moon; and the earth being between the ſun and moon, they are ſaid to be in *oppoſition.* The enlightened parts of the little figures on the outſide of the orbit, repreſent the appearance of the moon as ſeen by a ſpectator on the earth, *James.* Is the little figure then oppoſite E wholly dark to ſhew that the moon is inviſible at change?

Tutor, It is: and when it is at F a ſmall part of the illuminated hemiſphere is *within* the moon's orbit, and therefore to a ſpectator at T it appears *horned;* at G one half of the enlightened hemiſphere is viſible, and it is ſaid to be in *quadrature:* at H three-fourths of the enlightened part is viſible to the earth, and it is then ſaid to be *gibbous:* and at A the whole enlightened face of the moon is turned to the earth, and it is ſaid to be *full,* The ſame may be ſaid of the reſt.

The horns of the moon before conjunction or new moon, are turned to the *eaſt:* after conjunction they are turned to the *weſt.* How beautifully is the moon deſcribed by Milton:

——————— till the moon,
Riſing in clouded majeſty, at length,
Apparent Queen unveil'd her peerleſs light,
And o'er the dark her ſilver mantle threw.
Book iv. line 606.

Charles. I ſee the figure is intended to ſhew that the moon's orbit is elliptical: does ſhe alſo turn upon her axis?

Tutor. She does; and ſhe requires the ſame time for her diurnal rotation, as ſhe takes in completing her revolution about the earth; and conſequently though every part of the moon is ſucceſſively preſented to the ſun, yet the ſame hemiſphere is always turned to the earth. This is known by obſervation with good teleſcopes.

James. Then the length of a day and night in the moon is equal to more than twenty nine days and a half of our's.

Tutor. It is ſo: and therefore as the length of her year, which is meaſured by her journey round the ſun, is equal to that of our's, ſhe can have but about twelve days and one third in a year. Another remarkable circumſtance relating to the moon, is that the hemiſphere next the earth is never in darkneſs, for in the poſition E when it is turned from the ſun, it is illuminated by light reflected from the earth, in the ſame manner as we are enlightened by a full moon. But the other hemiſphere of the moon has a fortnight's light and darkneſs by turns.

Charles. Can the earth, then, be conſidered as a ſatellite to the moon?

Tutor. It would, perhaps, be inaccurate to denominate the larger body a ſatellite to the ſmaller, but with regard to affording reflected light, the earth is to the moon, what the moon is to the earth, and ſubject to the ſame changes of horned, gibbous, full, &c.

Charles. But it muſt appear much larger than the moon.

Tutor. The earth will appear to the inhabitants of the moon, about 13 times as large as the moon appears to us. When it is *new moon* to us, it is *full earth* to them, and the reverſe.

James. Is the moon then inhabited as well as the earth?

Tutor. Though we cannot demonſtrate this fact, yet there are many reaſons to induce us to believe it: for the moon is a ſecondary planet of conſiderable ſize;—its ſurface is diverſified like that of the earth with mountains and vallies;—the former have been meaſured by Dr. Herſchel, and ſome of them found to be about a mile in height. The ſituation of the moon, with reſpect to the ſun, is much like that of the earth, and by a rotation on her axis, and a ſmall inclination of that axis to the plane of her orbit, ſhe enjoys, though not a conſiderable, yet an agreeable variety of day and night and of ſeaſons. To the moon, our globe appears a capital ſatellite, undergoing the ſame changes of illumination, as the moon does to the earth. The ſun and ſtars riſe and ſet there as they do here, and heavy bodies will fall on the moon as they do on the earth. Hence we are led to conclude that like the earth, the moon alſo is inhabited. Dr. Herſchel diſcovered ſome years ago three volcanoes all burning in the moon; but no large ſeas or tracks of water have been obſerved there, nor is the exiſtence of a lunar atmoſphere certain. Therefore her inhabitants muſt materially differ from thoſe who live upon the earth.

CONVERSATION XV.

Of Eclipſes.

CHARLES. Will you, Sir, explain to us the nature and cauſes of eclipſes?

Tutor. I will, with great pleaſure. You muſt obſerve, then, that eclipſes depend upon this ſimple principle, that all opaque or dark bodies when expoſed to any light, and therefore to the light of the ſun, caſt a ſhadow behind them in an oppoſite direction.

James. The earth being a body of this kind muſt caſt a very large ſhadow on its ſide which is oppoſite to the ſun.

Tutor. It does: and an eclipſe of the moon happens when the earth T (Plate III. Fig. 12.) paſſes between the ſun S and the moon M, and it is occaſioned by the earth's ſhadow being caſt on the moon.

Charles. When does this happen?

Tutor. It is only when the moon is full or in *oppoſition*, that it comes within the ſhadow of the earth.

James. Eclipſes of the moon, however, do not happen every time it is full; what is the reaſon of this?

Tutor. Becauſe the orbit of the moon does not coincide with the plane of the earth's orbit, but one half of it is elevated about five degrees and a third above it, and the other half is as much below it: and therefore, unleſs the full moon happen in or near one of the nodes, that is in or near the points in which the two orbits interſect each other, ſhe will paſs above, or below the ſhadow of the earth, in which caſe there can be no eclipſe.

Charles. What is the greateſt diſtance from the node, at which an eclipſe of the moon can happen?

Tutor. There can be no eclipſe, if the moon, at the time when ſhe is full, be more than 12 degrees from the node; when ſhe is within that diſtance, there will be a *partial*, or *total* eclipſe, according as a part, or the whole diſk or face of the moon falls within the earth's ſhadow. If the eclipſe happen exactly when the moon is full in the node, it is called a central eclipſe.

James. I ſuppoſe the duration of the eclipſe laſts all the time that the moon is paſſing through the ſhadow.

Tutor. It does: and you obſerve that the ſhadow is conſiderably wider than the moon's diameter, and therefore an eclipſe of the moon laſts ſometimes three or four hours. The ſhadow alſo you perceive is of a conical ſhape, and conſequently, as the moon's orbit is an ellipſe and not a circle, the moon will, at different times, be eclipſed when ſhe is at different diſtances from the earth.

Charles. And according as the moon is nearer to, or farther from the earth, the eclipſe will be of a greater or leſs duration; for the ſhadow being conical becomes leſs and leſs, as the diſtance from the body by which it is caſt is greater.

Tutor. It is by knowing exactly at what diſtance the moon is from the earth, and of courſe the width of the earth's ſhadow at that diſtance, that all eclipſes are calculated, with the greateſt accuracy, for many years before they happen. Now, it is found that in all eclipſes, the ſhadow of the earth is conical, which is a demonſtration, that the body by which it is projected is of a ſpherical form, for no other ſort of figure would, in *all poſitions*, caſt a conical ſhadow. This is mentioned as another proof, that the earth is a ſpherical body.

James. It ſeems to me to prove another thing, viz. that the ſun muſt be a larger body than the earth.

Tutor. Your concluſion is juſt, for if the two bodies were equal to one another (Plate III. Fig. 13.) the ſhadow would be cylindrical: and if the earth were the larger body, (Plate III. Fig. 14.) its ſhadow would be of the figure of a cone, which had loſt its vertex, and the farther it were extended the larger would it become. In either caſe it would run out to an infinite ſpace, and accordingly muſt ſometimes involve in it the other planets, and eclipſe them, which is contrary to fact. Therefore, ſince the earth is neither larger than, nor equal to the ſun, it muſt be the leſſer body. —We will now proceed to the eclipſes of the ſun.

Charles. How are theſe occaſioned?

Tutor. An eclipſe of the ſun happens when the moon M, paſſing between the ſun S and the earth T, (Plate III. Fig. 15.) intercepts the ſun's light.

James. The ſun then can be eclipſed only at the new moon.

Tutor. Certainly; for it is only when the moon is in *conjunction*, that it can paſs directly between the ſun and earth.

Charles. Is it only when the moon at her conjunction, is near one of its nodes, that there can be an eclipſe of the ſun?

Tutor. An eclipſe of the ſun depends upon this circumſtance: for unleſs the moon is in, or near one of its nodes, ſhe cannot appear in the ſame plane with the ſun, or ſeem to paſs over his diſk. In every other part of the orbit ſhe will appear above or below the ſun. If the moon be *in* one of the nodes ſhe will, in moſt caſes, cover the whole diſk of the ſun, and produce a *total* eclipſe; if ſhe be any where within about 16 degrees of a node, a *partial* eclipſe will be produced.

The ſun's diameter is ſuppoſed to be divided into 12 equal parts called *digits*, and in every partial eclipſe, as many of theſe parts of the ſun's diameter, as the moon covers, ſo many digits are ſaid to be eclipſed.

James. I have heard of *annular* eclipſes, what are they, Sir?

Tutor. When a ring of light appears round the edge of the moon during an eclipſe of the ſun, it is ſaid to be annular, from the latin word *annulus*, a *ring*: theſe kind of eclipſes are occaſioned by the moon being at her greateſt diſtance from the earth at the time of an eclipſe, becauſe in that ſituation, the vertex or tip of the cone of the moon's ſhadow does not reach the ſurface of the earth.

Charles. How long can an eclipſe of the ſun laſt?

Tutor. A total eclipſe of the ſun is a very curious and uncommon ſpectacle; and total darkneſs cannot laſt more than three or four minutes. Of one that was obſerved in Portugal 150 years ago, it is ſaid that the darkneſs was greater than that of the night;—that ſtars of the firſt magnitude made their appearance;—and that the birds were ſo terrified that they fell to the ground.

James. Was this viſible only at Portugal?

Tutor. The moon being a body much ſmaller than the earth; and having alſo a conical ſhadow, can with that ſhadow only cover a ſmall part of the earth; whereas an eclipſe of the moon may be ſeen by all thoſe that are on that hemiſphere which is turned towards it. (See Plate III. Fig. 15 and 12.)—You will alſo obſerve, that an eclipſe of the ſun may be *total* to the inhabitants near the middle of the earth's diſk, and *annular* to thoſe, in places near the edges of the diſk, for in the former caſe the moon's ſhadow will reach the earth, and in the latter, on account of the earth's ſphericity, it will not.

Charles. Have not eclipſes been eſteemed as omens preſaging ſome direful calamity?

Tutor. Till the cauſes of theſe appearances were diſcovered, they were generally beheld with terror by the inhabitants of the world, which fact is beautifully alluded to by Milton in the 1ſt book of Paradiſe Loſt, line 594:

——————— As when the ſun, new riſen,
Looks through the horizontal miſty air
Shorn of his beams, or from behind the moon,
In dim eclipſe, diſaſtrous twilight ſheds
On half the nations, and with fear of change
Perplexes monarchs.

CONVERSATION XVI.

Of the Tides.

TUTOR. We will proceed to the conſideration of the *Tides*, or the flowing and ebbing of the ocean.

James. Is this ſubject connected with aſtronomy?

Tutor. It is, inaſmuch as the tides are occaſioned by the attraction of the ſun and moon upon the waters, but more particularly by that of the latter. You will readily conceive that the tides are dependent upon ſome known and determinate laws, becauſe, if you turn to the ephemeris, or indeed to almoſt any almanac, you will ſee the exact time of high water at London-bridge for every day in the year.

Charles. I have frequently wondered how this could be known with ſuch a degree of accuracy: indeed there is not a waterman that plies at the ſtairs but can readily tell when it will be high water.

Tutor. The generality of the watermen are probably as ignorant as yourſelf of the cauſe by which the waters flow and ebb, but by experience they know, that the time of high water differs on each day about three quarter's of an hour, or a little more or leſs, and therefore, if it be high water to-day at ſix o'clock, they will, at a gueſs, tell you, that to-morrow the tide will not be up till a quarter before ſeven.

James. Will you explain the cauſes?

Tutor. I will endeavour to do this in an eaſy and conciſe manner, without fatiguing your memory with a great variety of particulars:

> The ebbs of tides, and their myſterious flow,
> We, as art's elements, ſhall underſtand.
>
> DRYDEN.

You muſt bear in your mind then, that the tides are occaſioned by the attraction of the ſun and moon upon the waters of the earth: perhaps a figure may be of ſome aſſiſtance to you. Let A *p* L *n* (Plate III. Fig. 16.) be ſuppoſed the earth, C its center; let the dotted circle repreſent a maſs of water covering the earth: let M be the moon in its orbit: and S the ſun.

Since the force of gravity or attraction diminiſhes as the ſquares of the distances increaſe*, the waters on the ſide A are more attracted by the moon M, than the central parts at C; and the central parts are more attracted than the waters at L; conſequently the waters at L will recede from the center; therefore while the moon is in the ſituation M, the waters will riſe towards *a* and *b* on the oppoſite ſides of the earth.

Charles. You mean that the waters will riſe at *a* by the immediate attraction of the moon M, and will riſe at *b*, by center C, receding and leaving them more elevated there.

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* See vol. I. p. 54.

Tutor. That is the explanation. It is evident that the quantity of water being the ſame, a riſe cannot take place at *a* and *b*, without the parts at P and N being at the ſame time depreſſed.

James. In this ſituation the water may be conſidered as partaking of an oval form.

Tutor. If the earth and moon were without motion, and the earth covered all over with water, the attraction of the moon would raiſe it up in a heap in that part of the ocean to which the moon is vertical, and there it would always continue; but by the rotation of the earth on its axis, each part of its ſurface to which the moon is vertical is preſented twice a day to the action of the moon, and thus are produced two floods and two ebbs:

> Alternate tides in ſacred order run.
>
> BLACKMORE.

Charles. How twice a day?

Tutor. In the poſition of the earth and moon as it is in our figure, the waters are raiſed at A by the direct attraction of the moon, and a tide is accordingly produced: but when, by the earth's rotation, A comes, 12 hours afterwards, into the poſition L, another tide is occaſioned by the receding of the waters there from the center.

James. You have told us that the tides are produced in thoſe parts of the earth to which the moon is vertical, but this effect is not confined to thoſe parts.

Tutor. It is not, but there the attraction of the moon has the greateſt effect; in all other parts her force is weaker, becauſe it acts in a more oblique direction.

Charles. Are there two tides in every 24 hours?

Tutor. If the moon were ſtationary this would be the caſe; but becauſe that body is alſo proceeding every day about 13 degrees from weſt to eaſt in her orbit, the earth muſt make more than one revolution on its axis before the ſame meridian is in conjunction with the moon, and hence two tides take place in about 24 hours and 50 minutes.

James. But I remember when we were at the ſea, that the tides roſe higher at ſome ſeaſons than at others: how do you account for this?

Tutor. The moon goes round the earth in an elliptic orbit, and therefore ſhe approaches nearer to the earth in ſome parts of her orbit, than in others. When ſhe is neareſt, the attraction is the ſtrongeſt, and conſequently it raiſes the tides moſt: and when ſhe is fartheſt from the earth, her attraction is the leaſt, and the tides the loweſt.

James. Do they riſe to different heights in different places?

Tutor. They do: In the Black-Sea and the Mediterranean the tides are ſcarcely perceptible. At the mouth of the Indus the water riſes and falls full 30 feet. The tides are remarkably high on the coaſts of Malay; in the Straits of Punda; in the Red-Sea, along the coaſts of China, Japan, &c. In general the tides riſe higheſt and ſtrongeſt in thoſe places that are narroweſt.

Charles. You ſaid the ſun's attraction occaſioned tides as well as that of the moon.

Tutor. It does: but owing to the immenſe diſtance of the ſun from the earth, it produces but a ſmall effect in compariſon of the moon's attraction. Sir Iſaac Newton computed, that the force of the moon raiſed the waters in the great ocean 10 feet, whereas that of the ſun raiſed it only 2 feet. When both the attraction of the ſun and moon act in the ſame direction; that is at new and full moon, the combined forces of both raiſe the tide 12 feet. But when the moon is in her quarters, the attraction of one of theſe bodies raiſes the water, while that of the other depreſſes it; and therefore, the ſmaller force of the ſun muſt be ſubtracted from that of the moon, conſequently the tides will be no more than 8 feet. The higheſt tides are called ſpring-tides, and the loweſt are denominated neap-tides.

James. I underſtand that in the former caſe, the height to which the tides are raiſed, muſt be calculated by *adding* together the attractions of the ſun and moon; and in the latter, it muſt be eſtimated by the *difference* of theſe attractions.

Tutor. You are right. When the ſun and moon are both vertical to the equator of the earth, and the moon at her leaſt diſtance from the earth, then the tides are higheſt.

Charles. Do the higheſt tides happen at the Equinoxes?

Tutor. Strictly ſpeaking, theſe tides do not happen till ſome little time after, becauſe in this, as in other caſes, the actions do not produce the greateſt effect when they are at the ſtrongeſt, but ſome time afterwards: thus the hotteſt part of the day is not when the ſun is on the meridian, but between two and four o'clock in the afternoon —Another circumſtance muſt be taken into conſideration: the ſun being nearer to the earth in winter than in ſummer, it is of courſe nearer to it in February and October, than in March and September; and therefore all theſe things being put together, it will be found that the greateſt tides happen a little before the vernal, and ſome time after the autumnal Equinoxes.

CONVERSATION XVII.

Of the Harveſt Moon.

TUTOR. From what we ſaid yeſterday you will eaſily underſtand the reaſon why the moon riſes about three quarters of an hour later every day than on the one preceding.

Charles. It is owing to the daily progreſs which the moon is making in her orbit, on which account any meridian on the earth muſt make more than one complete rotation on its axis, before it comes again into the ſame ſituation with reſpect to the moon that it had before. And you told us that this occaſioned a difference of about 50 minutes.

Tutor. At the equator this is generally the difference of time between the riſing of the moon on one day and the preceding. But in places of conſiderable latitude, as that in which we live, there is a remarkable difference about the time of harveſt, when at the ſeaſon of full moon ſhe riſes for ſeveral nights together only about 20 minutes later on the one day than on that immediately preceding. By thus ſucceeding the ſun before the twilight is ended, the moon prolongs the light to the great benefit of thoſe who are engaged in gathering in the fruits of the earth; and hence the full moon at this ſeaſon is called the harveſt moon. It is believed that this was obſerved by perſons engaged in agriculture, at a much earlier period than it was noticed by aſtronomers; the former aſcribed it to the goodneſs of the Deity, not doubting but that he had ſo ordered it on purpoſe for their advantage.

James. But the people at the equator do not enjoy this benefit.

Tutor. Nor is it neceſſary that they ſhould, for in thoſe parts of the earth, the ſeaſons vary but little, and the weather changes but ſeldom, and at ſtated times; to them, then, moon-light is not wanting for gathering the fruits of the earth.

Charles. Can you explain how it happens, that the moon at this ſeaſon of the year riſes one day after another with ſo ſmall a difference of time?

Tutor. With the aſſiſtance of a globe I could at once clear the matter up. But I will endeavour to give you a general idea of the ſubject without that inſtrument. That the moon loſes more time in her riſings when ſhe is in one part of her orbit, and leſs in another, is occaſioned by the moon's orbit lying ſome times more oblique to the horizon than at others.

James. But the moon's path is not marked on the globe.

Tutor. It is not; you may, however, conſider it, without much error, as coinciding with the ecliptic. And in the latitude of London, as much of the ecliptic riſes about *Piſces* and *Aries* in two hours as the moon goes through in ſix days; therefore while the moon is in theſe ſigns ſhe differs but two hours in riſing for ſix days together; that is one day with another about 20 minutes later every day than on the preceding:

There is a time well known to huſbandmen,
In which the moon for many nights, in aid
Of their autumnal labours, cheers the duſk
With her full luſtre, ſoon as Phœbus hides
Beneath the horizon his propitious ray:
For as the angle of the line which bounds
The moon's career from the Equator, flows
Greater or leſs, the orb of Cynthia shines
With leſs or more of difference in riſe:
In *Aries* leaſt this angle: thence the moon
Riſes with ſmalleſt variance of times,
When in this ſign ſhe dwells; and moſt protracts
Her ſojourning in our enlighten'd ſkies.

Lofft.

Charles. Is the moon in thoſe ſigns at the time of harveſt?

Tutor. In Auguſt and September

you know that the ſun appears in Virgo and Libra, and of courſe when the moon is *full* ſhe muſt be in the oppoſite ſigns, viz. *Piſces* and *Aries.*

James. Are there then two full moons that afford us this advantage?

Tutor. There are, the one when the ſun is in Virgo, which is called the *harveſt* moon; the other when the ſun is in Libra, and which being leſs advantageous, is called the *hunter's* moon. You ought to be told that when the moon is in Virgo and Libra, then ſhe riſes with the greateſt difference of time, viz. an hour and quarter later every day than the former.

Charles. Will you explain, Sir, how it is that the people at the equator have no harveſt moon?

Tutor. At the equator, the north and ſouth poles lie in the horizon, and therefore the ecliptic makes the ſame angle ſouthward with the horizon when Aries riſes, as it does northward when Libra riſes; but as the harveſt moon depends upon the different angles at which different parts of the ecliptic riſes, it is evident there can be no harveſt moon at the equator.

The farther any place is from the equator, if it be not beyond the polar circles, the angle which the ecliptic makes with the horizon, when Piſces and Aries riſe, gradually diminiſhes, and therefore when the moon is in theſe ſigns ſhe riſes with a nearly proportionable difference later every day than on the former, and this is more remarkable about the time of full moon.

James. Why have you excepted

the ſpace on the globe beyond the polar circles?

Tutor. At the polar circles, when the ſun touches the ſummer tropic he continues 24 hours above the horizon; and 24 hours below it when he touches the winter tropic. For the ſame reaſon the full moon neither riſes in the ſummer, when ſhe is not wanted; nor ſets in the winter when her preſence is ſo neceſſary. Theſe are the only two full moons which happen about the tropics; for all the others riſe and ſet. In ſummer the full moons are low, and their ſtay above the horizon ſhort: in winter they are high, and ſtay long above the horizon. A wonderful diſplay this of the divine wiſdom and goodneſs, in apportioning the quantity of light ſuitable to the various neceſſities of the inhabitants of the earth, according to their different ſituations.

Charles. At the poles, the matter is I ſuppoſe ſtill different.

Tutor. There one half of the ecliptic never ſets and the other half never riſes; conſequently the ſun continues one half year above the horizon, and the other half below it. The full moon being always oppoſite to the ſun can never be ſeen to the inhabitants of the poles, while the ſun is above the horizon. But all the time that the ſun is below the horizon, the full moons never ſet. Conſequently to them the full moon is never viſible in their ſummer; and in their winter they have her always before and after the full, ſhining for 14 of our days and nights without intermiſſion. And when the ſun is depreſſed the loweſt under the horizon, then the moon aſcends with her higheſt altitude.

James. This indeed exhibits in a high degree the attention of Providence to all his creatures. But if I underſtand you, the inhabitants of the poles have in their winter a fortnight's light and darkneſs by turns.

Tutor. This would be the caſe for the whole ſix months that the ſun is below the horizon, if there were no refraction*; and no ſubſtitute for the light of the moon. But by the atmoſphere's refracting the ſun's rays, he becomes viſible a fortnight ſooner, and continues a fortnight longer in ſight than he would otherwiſe do were there no ſuch property belonging to the atmoſphere. And in thoſe parts of the winter, when it would be abſolutely dark in the abſence of the moon, the brilliancy of the *Aurora Borealis*, is probably ſo great as to afford a very comfortable degree of light. Mr. Hearne in his travels near the polar circle, has this remark in his journal; "December 24. The days were ſo ſhort, that the ſun only took a circuit of a few points of the compaſs above the horizon, and did not at its greateſt altitude riſe half way up the trees. The brilliancy of the Aurora Borealis, however, and of the ſtars, even without the aſſiſtance of the moon, made amends for this deficiency, for it was frequently ſo light all night, that I could ſee to read a ſmall print."

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* The ſubject of refraction will be very particularly explained when we come to Optics.

Theſe advantages are poetically deſcribed by our Thomſon:

By dancing meteors then, that ceaſeleſs ſhake
A waving blaze refracted o'er the heavens,
And vivid moons, and ſtars that keener play
With double luſtre from the gloſſy waſte;
Ev'n in the depth of Polar Night, they find
A wondrous day: enough to light the chaſe,
Or guide their daring ſteps to Finland-fairs.

WINTER, l. 859.

CONVERSATION XVIII.

Of Mercury.

TUTOR. Having fully deſcribed the earth and the moon, the former a primary planet, and the latter its attendant ſatellite, or ſecondary planet, we ſhall next conſider the other planets in their order, with which, however, we are leſs intereſted.

MERCURY, you recollect, is the planet neareſt the ſun; and Venus is the ſecond in order. Theſe are called inferior planets.

Charles. Why are they thus denominated?

Tutor. Becauſe they both revolve in orbits which are included *within* that of the earth; thus (Plate 1. Fig. 2.) Mercury makes his annual journey round the ſun in the orbit *a*; Venus in *b*, and the earth, farther from that luminary than either of them, makes his circuit in *t*.

James. How is this known?

Tutor. By obſervation: for by attentively watching the progreſs of theſe bodies, it is found that they are continually changing their places among the fixed ſtars, and that they are never ſeen in oppoſition to the ſun, that is, they are never ſeen in the weſtern ſide of the heavens in the morning when he appears in the eaſt; nor in the eaſtern part of the heavens in the evening when the ſun appears in the weſt.

Charles. Then they may be conſidered as attendants upon the ſun?

Tutor. They may: Mercury is never ſeen from the earth at a greater diſtance from the ſun than about 28 degrees, or about as far as the moon appears to be from the ſun on the ſecond day after its change; hence it is that we ſo ſeldom ſee him; and when we do, it is for ſo ſhort a time, and always in twilight, that ſufficient obſervations have not been made to aſcertain whether he has a diurnal motion on its axis.

James. Would you then conclude that he has ſuch a motion?

Tutor. I think we ought; becauſe it is known to exiſt in all thoſe planets upon which obſervations of ſufficient extent have been made, and therefore we may ſurely infer, without much chance of error, that it belongs alſo to Mercury, and the Herſchel planet, the former from its vicinity to the ſun, and the latter from its great diſtance from that body, having at preſent eluded the inveſtigation of the moſt indefatigable aſtronomers.

Charles. At what diſtance is Mercury from the ſun?

Tutor. He revolves round that body at about 37 millions of miles diſtance, in 88 days nearly; and therefore you can now tell me how many miles he travels in an hour.

James. I can, for ſuppoſing his orbit circular, I muſt multiply the 37 millions by 6*, which will give 222 millions of miles for the length of his orbit; this I ſhall divide by

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* See Vol. II. p. 80.

88, the number of days he takes in performing his journey, and the quotient reſulting from this, muſt be divided by 24 for the number of hours in a day; and by theſe operations, I find that Mercury travels at the rate of more than 105,000 miles in an hour.

Charles. How large is Mercury?

Tutor. He is the ſmalleſt of all the planets. His diameter is ſomething more than 3200 miles in length.

James. His ſituation being ſo much nearer to the ſun than ours, he muſt enjoy a conſiderably greater ſhare of its heat and light.

Tutor. So much ſo, as would indeed infallibly burn every thing belonging to the earth to atoms, were ſhe ſimilarly ſituated. The heat of the ſun at Mercury, muſt be 7 times greater than our ſummer heat:

————————Mercury the firſt
Near bordering on the day, with ſpeedy wheel
Flies ſwifteſt on, inflaming where he comes
With *ſeven-fold* ſplendor, all the azure road.

MALLET'S EXCURSION.

Charles. And do you imagine, that thus circumſtanced, this planet can be inhabited?

Tutor. Not by ſuch beings as we are: you and I could not long exiſt at the bottom of the ſea; yet the ſea is the habitation of millions of living creatures; why then may there not be inhabitants in Mercury, fitted for the enjoyment of the ſituation which that planet is calculated to afford? If there be not, we muſt be at a loſs to know why ſuch a body was formed, certainly it could not be intented for our benefit, for it is rarely even ſeen by us:

Aſk for what end the heavenly bodies ſhine?
Earth for whoſe uſe? Pride anſwers, "'Tis for mine:
——————— ſuns to light me riſe,
My footſtool earth, my canopy the ſkies."

POPE.

But do theſe worlds diſplay their beams, or guide
Their orbs, to ſerve thy uſe, to pleaſe thy pride?
Thyſelf but duſt, thy ſtature but a ſpan,
A moment thy duration; fooliſh man!
As well may the minuteſt emmet ſay,
That Caucaſus was raiſed to pave his way:
The ſnail, that Lebanon's extended wood
Was deſtined only for his walk and food:
The vileſt cockle, gaping on the coaſt
That rounds the ample ſeas, as well may boaſt,
The craggy rock projects above the ſky,
That he in ſafety at its foot may lie;
And the whole ocean's confluent waters ſwell,
Only to quench his thirſt, or move and blanch his ſhell.

PRIOR.

CONVERSATION XIX.

Of Venus.

TUTOR. We now proceed to Venus, the ſecond planet in the order of the ſolar ſyſtem, but by far the moſt beautiful of them all:

Faireſt of ſtars, laſt in the train of night,
If better thou belong not to the dawn,
Sure pledge of day, that crown'ſt the ſmiling
morn
With thy bright circlet, praiſe him in thy ſphere,
While day ariſes, that ſweet hour of prime.
MILTON.

James. How far is Venus from the ſun?

Tutor. That planet is 68 millions of miles from the ſun, and ſhe finiſhes her journey in 224½ days, conſequently ſhe muſt travel at the rate of 75,000 miles in an hour.

Charles. Venus is larger than Mercury I dare ſay.

Tutor. Yes, ſhe is nearly as large as the earth, which ſhe reſembles alſo in other reſpects, her diameter being about 7700 miles in length, and ſhe has a rotation about her axis in 23 hours and 20 minutes. The quantity of light and heat which ſhe enjoys from the ſun, muſt be double that which is experienced by the inhabitants of this globe.

James. Is there alſo a difference in her ſeaſons, as there is here?

Tutor. Yes, in a much more conſiderable degree. The axis of Venus inclines about 75 degrees, but that of the earth inclines only 23½ degrees, and as the variety of the ſeaſons in every planet depends on the degree of the inclination of its axis, it is evident that the ſeaſons muſt vary more with Venus than with us.

Charles. Venus appears to us larger ſometimes than at others.

Tutor. She does; and this, with other particulars, I will explain by means of a figure. Suppoſe S (Plate III. Fig. 17.) to be the ſun, T the earth in her orbit, and *a*, *b*, *c*, *d*, *e*, *f*, Venus in her's: now it is evident, that when Venus is at *a* between the ſun and earth, ſhe would, if viſible, appear much larger than when ſhe is at *d* in oppoſition.

James. That is becauſe ſhe is ſo much nearer in the former caſe than in the latter, being in the ſituation *a* but 27 millions of miles from the earth T, but at *d* ſhe is 163 millions of miles off.

Tutor. Now as Venus paſſes from *a*, through *b*, *c*, to *d*, ſhe may be obſerved by means of a good teleſcope, to have all the ſame phaſes as the moon has in paſſing from new to full: therefore when ſhe is at *d* ſhe is full, and is ſeen among the fixed ſtars in the beginning of Cancer: during her journey from *d* to *e* ſhe proceeds with a *direct* motion in her orbit, and at *e* ſhe is ſeen in Leo, and will appear to an inhabitant of the earth, for a few days to be *ſtationary*, not ſeeming to change her place among the fixed ſtars, for ſhe is coming toward the earth in a direct line: but in paſſing from *e* to *f*, though ſtill with a direct motion, yet to a ſpectator at T, her courſe will ſeem to be back again, or *retrograde*, for ſhe will ſeem to have gone back from *z* to *y*; her path will appear retrograde till ſhe gets to *c*, when ſhe will again appear *ſtationary*, and afterwards from *c* to *d*, and from *d* to *e* it will be *direct* among the fixed ſtars.

Charles. When is Venus an evening, and when a morning ſtar?

Tutor. She is an evening ſtar all the while ſhe appears *eaſt* of the ſun, and a morning ſtar while ſhe is ſeen *weſt* of him:

Next Venus to the *weſtward* of the ſun
Full orbed her face, a golden plain of light
Circles her larger round. Fair *morning* ſtar
That leads on dawning day to yonder world
The *ſeat of Man.*

MALLET'S EXCURSION.

When ſhe is at *a* ſhe will be inviſible, her dark ſide being towards us, unleſs ſhe be exactly in the node, in which caſe ſhe will paſs over the ſun's face like a little black ſpot.

James. Is that called the tranſit of Venus?

Tutor. It is; and it happens twice only in about 120 years. By this phenomenon aſtronomers have been enabled to aſcertain with great accuracy the diſtance of the earth from the ſun; and having obtained this, the diſtances of the other planets are eaſily found. By the two tranſits which happened in 1761, and 1769, it was clearly demonſtrated, that the mean diſtance of the earth from the ſun was between 95 and 96 millions of miles.

Charles. How do you find the

diſtances of the other planets from the ſun, by knowing that of the earth*?

Tutor. I will endeavour to make this plain to you. Kepler, a great aſtronomer, diſcovered that all the planets are ſubject to one general law, which is, that *the ſquares of their periodical times, are proportional to the cubes of their diſtances from the ſun.*

James. What do you mean by the *periodical times?*

Tutor. I mean the times which the planets take in revolving round the ſun; thus the periodical time of the earth is 365¼ days; that of Venus 224¼ days; that of Mercury 88 days.

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* The remainder of this converſation may be omitted by thoſe young perſons who are not ready in arithmetical operations. The author, however, knows from experience, that children may, at a very early age, be brought to underſtand theſe higher parts of arithmetic.

Charles How then would you find the diſtance of Mercury from the ſun?

Tutor. By the rule of three; I would ſay as the ſquare of 365 days (the time which the earth takes in revolving about the ſun) is to the ſquare of 88 days, (the time in which Mercury revolves about the ſun) ſo is the cube of 95 millions (the diſtance in miles of the earth from the ſun) to a fourth number.

James And is that fourth number the diſtance in miles of Mercury from the ſun?

Tutor. No: you muſt extract the cube root of that number, and then you will have about 37 millions of miles for the anſwer, which is the true diſtance at which Mercury revolves about the ſun.

CONVERSATION XX.

Of Mars.

TUTOR. Next to Venus is the earth and her ſatellite the moon, but of theſe ſufficient notice has already been taken, and therefore we ſhall paſs on to the planet Mars, which is known in the heavens by a duſky red appearance. Mars together with Jupiter, Saturn and the Herſchel are called ſuperior planets, becauſe the orbit of the earth is encloſed by their orbits.

Charles. At what diſtance is Mars from the ſun?

Tutor. About 144 millions of miles; the length of his year is equal to 687 of our days, and therefore he travels at the rate of more than 53 thouſand miles in an hour: his diurnal rotation on his axis is performed in 24 hours and 39 minutes, which makes his figure that of an oblate ſpheroid.

James. How is the diurnal motion of this planet diſcovered?

Tutor. By means of a very large ſpot which is ſeen diſtinctly on his face, when he is in that part of his orbit which is oppoſite to the ſun and earth.

Charles. Is Mars as large as the earth?

Tutor. No: his diameter is only 4189 miles in length, which is but little more than half the length of the earth's diameter. And owing to his diſtance from the ſun he will not enjoy one half of the light and heat which we enjoy.

James. And yet, I believe, he has not the benefit of a moon.

Tutor. No moon has ever been diſcovered belonging either to Mercury, Venus, or Mars.

Charles. Do the ſuperior planets exhibit ſimilar appearances of direct and retrograde motion to thoſe of the inferior planets?

Tutor. They do: ſuppoſe s (Plate IV. Fig. 18.) the ſun; *a*, *b*, *d*, *f*, *g*, *h* the earth in different parts of its orbit, and *m* Mars in his orbit. When the earth is at *a*, Mars will appear among the fixed ſtars at *x*: when by its annual motion the earth has arrived at *b*, *d* and *f*, reſpectively, the planet Mars will appear in the heavens at *y*, *z*, and *w*: when the earth has advanced to *g*, Mars will appear ſtationary at *o*: to the earth in its journey from *g* to *h* the planet will ſeem to go backwards or retrograde in the heavens from *o* to *z*, and this retrograde motion will be apparent till the earth has arrived at *a*, when the planet will again appear ſtationary.

James. I perceive that Mars is retrograde when in *oppoſition*, and the ſame is I ſuppoſe applicable to the other ſuperior planets, but the retrograde motion of Mercury and Venus is when thoſe planets are in *conjunction*.

Tutor. You are right: and you ſee the reaſon, I dare ſay, why the ſuperior planets may be in the weſt in the morning when the ſun riſes in the eaſt, and the reverſe.

Charles. For when the earth is at *d*, Mars may be at at *n*, in which caſe the earth is between the ſun and the planet: I obſerve alſo that the planet Mars, and conſequently the other ſuperior planets, are much nearer the earth at one time than at others.

Tutor. The difference with reſpect to Mars is no leſs than 190 million of miles, the whole length of the orbit of the earth. This will be a proper time to explain what is meant by the *Heliocentric* longitude of the planets referred to in the Ephemeris.

James. Yes, I remember you promiſed to explain this when you came to ſpeak of the planets; I do not know the meaning of the word heliocentric.

Tutor. It is a term uſed to expreſs the place of any heavenly body as ſeen from the ſun; whereas the *geocentric* place of a planet, is the poſition which it has when ſeen from the earth.

Charles. Will you ſhew us by a figure in what this difference conſiſts?

Tutor. I will: let s (Plate IV. Fig. 19.) repreſent the place of the ſun, *b* Venus in its orbit, *a* the earth in hers, and *c* Mars in his orbit, and the outermoſt circle will repreſent the ſphere of fixed ſtars. Now to a ſpectator on the earth *a*, Venus will appear among the fixed ſtars in the beginning of Scorpio, but as viewed from the ſun, ſhe will be ſeen beyond the middle of Leo. Therefore the *Geocentric* longitude of Venus will be in Scorpio, but her *Heliocentric* longitude will be in Leo. Again, to a ſpectator at *a*, the Planet Mars at *c*, will appear among the fixed ſtars towards the end of the ſign of Piſces; but as viewed from the ſun he will be ſeen at the beginning of the ſign Aries: conſequently the *geocentric* longitude of Mars is in Piſces; but his *heliocentric* longitude is in Aries.

CONVERSATION XXI.

Of Jupiter.

TUTOR. We now come to Jupiter, the largeſt of all the planets, which is eaſily known by his peculiar magnitude and brilliancy.

Charles. Is Jupiter larger than Venus?

Tutor. Though he does not appear ſo large, yet the magnitude of Venus bears but a very ſmall proportion to that of Jupiter, whoſe diameter is 90,000 miles in length, conſequently his bulk will exceed the bulk of Venus 1500 times: his diſtance from the ſun is eſtimated at more than 490 million of miles.

James. Then he is *five* times farther from the ſun, than the earth, and conſequently, as light and heat diminiſh in the ſame proportion as the ſquares of the diſtances, from the illuminating body, increaſe, the inhabitants of Jupiter enjoy but a twenty-fifth part of the light and heat of the ſun that we enjoy.

Tutor. Another thing remarkable in this planet is, that it revolves on its axis, which is perpendicular to his orbit, in 10 hours, and in conſequence of this ſwift diurnal rotation, his equatorial diameter is 6000 miles greater than his polar diameter.

Charles. Since then a variety in the ſeaſons of a planet depends upon the inclination of the axis to its orbit, and ſince the axis of Jupiter has no inclination, there can be no difference in his ſeaſons, nor any in the length of his days and nights.

Tutor. You are right, his days and nights are always five hours each in length; and at his equator, and its neighbourhood, there is perpetual ſummer; and an everlaſting winter in the polar regions.

James. What is the length of his years?

Tutor. It is equal to nearly 12 of ours, for he takes 11 years, 314 days, and 10 hours, to make a revolution round the ſun, conſequently he travels at the rate of more than 28,000 miles in an hour.

This noble planet is accompanied with four ſatellites which revolve about him at different diſtances, and in different periodical times, the *firſt* in about 1 day and 18 hours: the *ſecond* in 3 days, 13 hours: the *third* in 7 days, 3 hours: and the *fourth* in 16 days and 16 hours.

Beyond the ſphere of *Mars* in diſtant ſkies,
Revolves the mighty magnitude of *Jove*
With kingly ſtate, the rival of the ſun.
About him round *four planetary moons*
On earth with wonder all night long beheld,
Moon above moon, his fair attendants dance.

MALLET'S EXCURSION.

Charles. And are theſe ſatellites, like our moon, ſubject to be eclipſed?

Tutor. They are; and theſe eclipſes are of conſiderable importance to aſtronomers, in aſcertaining with accuracy the longitude of different places on the earth.

By means of the eclipſes of Jupiter's ſatellites, a method has been alſo obtained of demonſtrating that the motion of light is *progreſſive*, and not *inſtantaneous* as was once ſuppoſed. Hence it is found, that the velocity of light is nearly 11,000 times greater than the velocity of the earth in its orbit, and more than a million of times greater than that of a ball iſſuing from a cannon. This diſcovery is alluded to by the laſt mentioned poet: ſpeaking of an obſerver of the eclipſes and Jupiter's ſatellites, he ſays,

By theſe obſerv'd, the *rapid progreſs finds*
Of *light* itſelf: how ſwift the headlong ray
Shoots from the ſun's height through unbounded ſpace.
At once enlight'ning air, and earth, and heaven.

Rays of light come from the ſun to the earth in 8 minutes, that is at the rate of 12 millions of miles in a minute nearly.

CONVERSATION XXII.

Of Saturn.

TUTOR. We are now arrived at Saturn in our deſcriptions, which till within theſe twenty years was eſteemed the moſt remote planet of the ſolar ſyſtem.

Charles. How is he diſtinguiſhed in the heavens?

Tutor. He ſhines with a pale dead light very unlike the brilliant Jupiter, yet his magnitude ſeems to vie with that of Jupiter himſelf. The diameter of Saturn is nearly 80 thouſand miles in length: his diſtance from the ſun is more than 900 million of miles, and he performs his journey round that luminary in a little leſs than 30 of our years, conſequently he muſt travel at a rate not much ſhort of 21,000 miles an hour.

James. His great diſtance from the ſun muſt render an abode on Saturn extremely cold and dark too in compariſon of what we experience here.

Tutor. His diſtance from the ſun being between 9 and 10 times greater than that of the earth, he muſt enjoy about 90 times leſs light and heat; it has nevertheleſs been calculated that the light of the ſun at Saturn is 500 times greater than what we enjoy from our *full moon*, *Charles.* The day-light at Saturn, then, cannot be very contemptible: I ſhould hardly have thought that the light of the ſun here was 500 times greater than that experienced from a full moon.

Tutor. So much greater is our meridian light than this, that during the ſun's abſence behind a cloud, when the light is much leſs ſtrong than when we behold him in all his glorious ſplendor, it is reckoned that our day-light is 90,000 times greater than the light of the moon at its full.

James. But Saturn has ſeveral moons, I believe?

Tutor. He is attended by *ſeven* ſatellites or moons, whoſe periodical times differ very much; the one neareſt to him performs a revolution round the primary planet in 22 hours and a half; and that which is moſt remote takes 79 days and 7 hours for his monthly journey: this laſt ſatellite is known to turn on its axis, and in its rotation is ſubject to the ſame law which our moon obeys, that is, it revolves on its axis in the ſame time in which it revolves about the planet.

Beſides the ſeven moons, Saturn is encompaſſed with two broad rings which are probably of conſiderable importance in reflecting the light of the ſun to that planet; the breadth of the inner ring is 20,000 miles, that of the outer ring 7200 miles, and the vacant ſpace between the two rings is 2839 miles. Theſe rings give Saturn a very different appearance to any of the other planets. Plate IV. Fig. 20. is a repreſentation of Saturn as ſeen through a good teleſcope. On the ſuppoſition that Saturn was the moſt remote planet of our ſyſtem, he is thus deſcribed by Mallet in his Excurſion.

Laſt, outmoſt Saturn walks his frontier round
The boundary of worlds; with his pale moons,
Faint glimmering through the gloom which
night has thrown
Deep-dyed and dead o'er this chill globe
forlorn:
An endleſs deſart, where extreme of cold
Eternal ſits, as in his native ſeat,
On wintry hills of never thawing ice,
Such *Saturn's* earth; and even here the ſight
Amid theſe doleful ſcenes, new matter finds
Of wonder and delight! a mighty *ring!*

Charles. Is it known whether Saturn turns on its axis?

Tutor. According to Dr. Herſchel it has a rotation about its axis in 12 hours 13¼ minutes: this he computed from the equatorial diameter being longer than the polar diameter in the proportion of 11 to 10. Dr. Herſchel has alſo diſcovered that the ring, juſt mentioned, revolves about the planet in 10 hours and a half.

CONVERSATION XXIII.

Of the Herſchel Planet.

TUTOR. We have but one other planet to deſcribe, that is the Herſchel.

James. Was it diſcovered by Dr. Herſchel?

Tutor. It was, on the 13th of March, 1781, and therefore by aſtronomers in general it is denominated the Herſchel planet: though by the Doctor himſelf it was named the Georgium Sidus, or Georgian Star, in honour of his preſent Majeſty George the third, who has for many years been a liberal patron to this great and moſt indefatigable aſtronomer.

Charles. I do not think, that I have ever ſeen this planet.

Tutor. Its apparent diameter is too ſmall to be diſcerned readily by the naked eye, but it may be eaſily diſcovered in a clear night, when it is above the horizon, by means of a good teleſcope, its ſituation being previouſly known from the Ephemeris.

James. Is it owing to the ſmallneſs of this planet, or to its great diſtance from the ſun that we cannot ſee it with the naked eye?

Tutor. Both theſe cauſes are combined: in compariſon of Jupiter and Saturn it is ſmall, his diameter being leſs than 35 thouſand miles in length; and his diſtance from the ſun is eſtimated at more than 1800 millions of miles from that luminary, around which, however, he performs his journey in 82 of our years, conſequently he muſt travel at the rate of 16,000 miles an hour.

Charles. But if this planet has been diſcovered only 22 years, how is it known that it will complete its revolution in 82 years.

Tutor. By a long ſeries of obſervations it was found to move with ſuch a veloſity as would carry it round the heavens in that period. Moreover when it was firſt diſcovered, it was in Gemini, and it is now (Auguſt, 1803) advanced to the 11° of Libra, more than a fourth part of its journey.

James. How many moons has the Herſchel Planet?

Tutor. He is attended by ſix ſatellites or moons, of which, the one neareſt to the planet performs his revolution round the primary in 5 days and 25 hours, but that which is the moſt remote from him takes 107 days and 16 hours for his journey.

Charles. Is there any idea formed as to the light and heat enjoyed by this planet?

Tutor. His diſtance from the ſun is 19 times greater than that of the earth, conſequently ſince the ſquare of 19 is 361, the light and heat experienced by the inhabitants of that planet, muſt be 361 times leſs than *we* derive from the rays of the ſun.

The proportion of light enjoyed by the Herſchel has been eſtimated at about equal to the effect of 248 of our full moons.

CONVERSATION XXIV.

Of Comets.

TUTOR. Beſides the ſeven primary planets, and the eighteen ſecondary ones or ſatellites, which we have been deſcribing, there are other bodies belonging to the ſolar ſyſtem called comets, to which Thomſon in his Summer beautifully alludes:

——————— Amid the radiant orbs
That more than deck, that animate the ſky,
The life-infuſing ſuns of other worlds;
Lo! from the dread immenſity of ſpace
Returning with accelerated courſe

The ruſhing *comet* to the ſun deſcends,
And as he ſinks below the ſhading earth,
With aweful train projected o'er the heavens,
The guilty nations tremble.

SUMMER. line 1702.

Charles. Do comets reſemble the planets in any reſpects?

Tutor. Like them they are ſuppoſed to revolve about the ſun in elliptical orbits, and to deſcribe equal areas in equal times; but they do not appear to be adapted for the habitation of animated beings, owing to the great degrees of heat and cold to which, in their courſe, they muſt be ſubjected.

The comet ſeen by Sir Iſaac Newton in the year 1680, was obſerved to approach ſo near the ſun, that its heat was eſtimated by that great man, to be 2000 times greater than that of red-hot iron.

James. It muſt have been a very ſolid body to have endured ſuch a heat without being entirely diſſipated.

Tutor. So indeed it ſhould ſeem: and a body thus heated muſt retain its heat a long time; for a red-hot globe of iron, of a ſingle inch in diameter, expoſed to the open air, will ſcarcely loſe all its heat in an hour; and it is ſaid, that a globe of red-hot iron as large as our earth, would ſcarcely cool in 50,000 years. See Enfield's Inſtitutes of Nat. Phil. p. 296. 2d. edit.

Charles. Are the periodical times of the comets known?

Tutor. Not with any degree of certainty; it was ſuppoſed that the periods of three of them had been diſtinctly aſcertained. The *firſt* of theſe appeared in the years 1531, 1607, and 1682, and it was expected to return every 75th year; and one, which was conjectured to be the ſame, was ſeen by Dr. Halley in 1758.

The *ſecond* of them appeared in 1532, and 1661, and it was expected that it would again make its appearance in 1789, but in this, the aſtronomers of the preſent day have been diſappointed.

The *third* was that which appeared 1680, and its period being eſtimated at 575 years cannot, upon that ſuppoſition, return until the year 2255. This laſt comet at its *greateſt* diſtance is eleven thouſand two hundred million of miles from the ſun, and its *leaſt* diſtance from the ſun's center was but four hundred and ninety thouſand miles; in this part of its orbit it travelled at the rate of 880,000 thouſand miles in an hour.

James. Do all bodies move faſter or ſlower in proportion as they are nearer to, or more diſtant from their center of motion?

Tutor. They do, for if you look back upon the laſt ſix or ſeven lectures, you will ſee that the Herſchel, which is the moſt remote planet in the ſolar ſyſtem, travels at the rate of 16,000 miles an hour; Saturn the next nearer in the order 21,000 miles; Jupiter 28,000 miles; Mars 53,000 miles; the earth 65,000 miles; Venus 75,000 miles; and Mercury at the rate of 105,000 miles in an hour. But here we come to a comet whoſe progreſſive motion in that part of its orbit which is neareſt to the ſun, is more than equal to eight times the velocity of Mercury.

Charles. Were not comets formerly dreaded, as awful prodigies intended to alarm the world?

Tutor. Comets are frequently accompanied with a luminous train called the tail, which is ſuppoſed to be nothing more than ſmoke riſing from the body in a line oppoſite to the ſun, but which, to uninformed people, has been a ſource of terror and diſmay, and to this opinion many of our poets have alluded,

——————————Where the *train*
Of comets wander in their eccentric ways
With infinite excurſion thro' th' immenſe
Of ether, traverſing from ſky to ſky
Ten thouſand regions, in their winding road

Whoſe length to trace imagination fails;
Various their paths————
While diſtant orbs with wonder and amaze
Mark their approach, and night by night alarm'd
Their dreaded progreſs watch, as of a foe
Whoſe march is ever fatal, in whoſe train
Famine and war, and deſolating plague,
Each on his pale horſe rides, the miniſters
Of angry heaven to ſcourge offending worlds!

MALLET'S EXCURSION.

CONVERSATION XXV.

Of the Sun.

TUTOR. Having given you a particular deſcription of the planets which revolve about the ſun, and alſo of the ſatellites which travel round the primary planets as central bodies while they are carried at the ſame time with theſe bodies round the ſun, we ſhall conclude our account of the ſolar ſyſtem by taking ſome notice of the ſun himſelf,

Informer of the planetary train,
Without whoſe quick'ning glance their cumbrous orbs

Were brute unlovely maſs inert and dead,
And not, as now, the green abodes of life.
THOMSON'S AUTUMN, line 1086.

James. You told us a few days ago that the ſun has a rotation on its axis, how is that known?

Tutor. By the ſpots on his ſurface it is known that he completes a revolution from weſt to eaſt on his axis in about 25 days, two days leſs than his *apparent* revolution, in conſequence of the earth's motion in her orbit, in the ſame direction.

Charles. Is the figure of the ſun globular?

Tutor. No; the motion about its axis renders it ſpheroidical, having its diameter at the equator longer than that which paſſes through the poles.

The ſun's diameter is equal to 100 diameters of the earth, and therefore his bulk muſt be a million of times greater than that of the earth, but the denſity of the matter of which it is compoſed, is four times leſs than the denſity of our globe.

We have already ſeen that by the attraction of the ſun, the planets are retained in their orbits, and that to him they are indebted for light, heat and motion:

Faireſt of Beings! firſt created light:
Prime cauſe of beauty! for from thee alone
The ſparkling gem, the vegetable race,
The nobler worlds that live and breathe their
charms,
The lovely hues peculiar to each tribe,
From thy unfailing ſource of ſplendor draw!
In thy pure ſhine, with tranſport I ſurvey
This firmament, and theſe her rolling worlds
Their magnitudes and motions.———

MALLET'S EXCURSION.

CONVERSATION XXVI.

Of the fixed Stars.

TUTOR. We will now put an end to our aſtronomical converſations by referring again to the fixed ſtars, which like our ſun ſhine by their own light.

Charles. Is it then certain that the fixed ſtars are of themſelves luminous bodies; and that the planets borrow their light from the ſun?

Tutor. By the help of teleſcopes it is known that Mercury, Venus, and Mars ſhine by a borrowed light, for like the moon, they are obſerved to have different phaſes according as they are differently ſituated with regard to the ſun. The immenſe diſtances of Jupiter, Saturn, and the Herſchel planet do not allow the difference between the perfect and imperfect illumination of their diſcs or phaſes to be perceptible.

Now the diſtance of the fixed ſtars from the earth is ſo great that reflected light would be much too weak ever to reach the eye of an obſerver here.

James. Is this diſtance aſcertained with any degree of preciſion?

Tutor. It is not: but it is known with certainty to be ſo great, that the whole length of the earth's orbit, viz. 190 million of miles, is but a point in compariſon of it; and hence it is inferred that the diſtance of the neareſt fixed ſtar cannot be leſs than a hundred thouſand times the length of the earth's orbit*; that is a hundred thouſand times 190 millions of miles, or 19,000,000,000,000 miles: this diſtance being immenſely great, the beſt method of forming ſome clear conception of it, is to compare it with the velocity of ſome moving body, by which it may be meaſured. The ſwifteſt motion with which we are acquainted is that of light, which as we have ſeen, is at the rate of 12 millions of miles in a minute: and yet light would be about 3 years in paſſing from the neareſt fixed ſtar to the earth.

A cannon-ball which may be made to move at the rate of 20 miles in a minute, would be 1800 thouſand years

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[*] See Dr. Enfield's Inſtitutes of Natural Philoſophy, p. 347. Second Edition, 1799.

in traverſing this diſtance. Sound, the velocity of which is 13 miles in a minute, would be more than 2 million 7 hundred thouſand years in paſſing from the ſtar to the earth. So that if it were poſſible for the inhabitants of the earth, to ſee the light; —to hear the ſound;—and to receive the ball of a cannon diſcharged at the neareſt fixed ſtar; they would not perceive the light of its exploſion for 3 years after it had been fired; nor receive the ball till 1800 thouſand years had elapſed; nor hear the report for 2 millions and 7 hundred thouſand years after the exploſion.

Charles. Are the fixed ſtars at different diſtances from the earth?

Tutor. Their magnitudes, as you know, appear to be different from one another, which difference may ariſe either from a diverſity in their real magnitudes, or in their diſtances, or from both theſe cauſes acting conjointly. It is the opinion of Dr. Herſchel that the different apparent magnitudes of the ſtars ariſe from the different diſtances at which they are ſituated, and therefore he concludes that ſtars of the ſeventh magnitude, are at ſeven times the diſtance from us that thoſe of the firſt magnitude are.

By the aſſiſtance of his teleſcopes he is able to diſcover ſtars at 497 times the diſtance of *Sirius* the Dog-ſtar: from which he infers that with more powerful inſtruments he ſhould be able to diſcover ſtars at ſtill greater diſtances.

James. I recollect that you told us once, that it had been ſuppoſed by ſome aſtronomers, that there might be fixed ſtars at ſo great a diſtance from us, that the rays of their light had not yet reached the earth, though they had been travelling at the rate of 12 millions of miles in a minute from the firſt creation to the preſent time.

Tutor. I did; it was one of the ſublime ſpeculations of the celebrated Huygens. Dr. Halley has alſo advanced what, he ſays, ſeems to be a metaphyſical paradox, viz. that the number of fixed ſtars muſt be more than finite, and ſome of them at a greater than a finite diſtance from others: and Mr. Addiſon has juſtly obſerved, that this thought is far from being extravagant, when we conſider that the univerſe is the work of infinite power, prompted by infinite goodneſs, and having an infinite ſpace to exert itſelf in; ſo that our imagination can ſet no bounds to it.

How diſtant ſome of the nocturnal ſuns!
So diſtant, ſays the ſage, 'twere not abſurd
To doubt, if beams, ſet out at Nature's birth,
Are yet arriv'd at this ſo foreign world;
Though nothing half ſo rapid as their flight.

YOUNG.

Charles. What can be the uſe of theſe fixed ſtars;—not to enlighten the earth, for a ſingle additional moon would give us much more light than them all, eſpecially if it were ſo contrived as to afford us its aſſiſtance at thoſe intervals when our preſent moon is below the horizon.

Tutor. You are right: they could not have been created for our uſe, ſince thouſands, and even millions, are never ſeen but by the aſſiſtance of glaſſes, to which but few of our race have acceſs. Your minds indeed are too enlightened to imagine, like children unaccuſtomed to reflection that all things were created for the enjoyment of man. The earth on which we live is but one of ſeven primary planets circulating perpetually round the ſun as a center, and with theſe are connected eighteen ſecondary planets or moons, all of which are probably teeming with living beings capable, though in different ways, of enjoying the bounties of the great firſt cauſe.

The fixed ſtars then are probably ſuns, which, like our ſun, ſerve to enlighten, warm, and ſuſtain other ſyſtems of planets and their dependant ſatellites.

James. Would our ſun appear as a fixed ſtar at any great diſtance?

Tutor. It certainly would: and Dr. Herſchel thinks there is no doubt, but that it is one of the heavenly bodies belonging to that tract of the heavens known by the name of the *milky way.*

Charles. I know the milky way in the heavens, but I little thought, that I had any concern with it otherwiſe than as an obſerver.

Tutor. The milky way conſiſts of fixed ſtars too ſmall to be diſcerned with the naked eye; and if our ſun be one of them, the earth and other planets are cloſely connected with this part of the heavens.

But, Gentlemen, it is time that we take our leave of this ſubject for the preſent. For your attention to thoſe inſtructions which on this and other topics, I have been able to communicate, accept my beſt thanks. For your future welfare and happineſs my heart is deeply intereſted. You will not, I flatter myſelf, very ſoon forget that connection which has ſubſiſted between us for a long courſe of years. From my mind the remembrance of your kindneſs can never be obliterated. Permit me, then, as a teſtimony of my gratitude and ſincere affection, to recommend to your future attention the works of nature and creation, by a careful inveſtigation of which you will neceſſarily be led to the contemplation and love of the God of Nature.

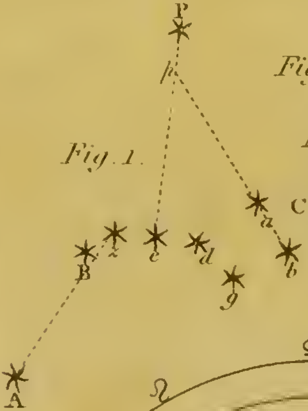
Your knowledge, young as you yet are, of the fundamental principles of Geometry and Algebra, is ſuch as to render ſcientific purſuits eaſy and pleaſant. And your underſtandings are not more capable of entering into the ſublime ſpeculations of ſcience, than your hearts are adapted to receive and cheriſh thoſe impreſſions of gratitude, which are the natural conſequences of enlarged and comprehenſive views of the being and perfections of the Deity. In all your ſtudies and purſuits, then, never forget, that

——————— you cannot go
Where UNIVERSAL LOVE not ſmiles around,
Suſtaining all yon orbs, and all their ſons;
From ſeeming evil ſtill educing good,
And better thence again, and better ſtill,
In infinite progreſſion.

THOMSON.

END OF THE SECOND VOLUME.

Printed b Bye and Law, St. John's-Square, Clerkenwell.



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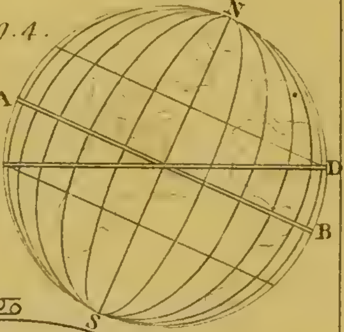

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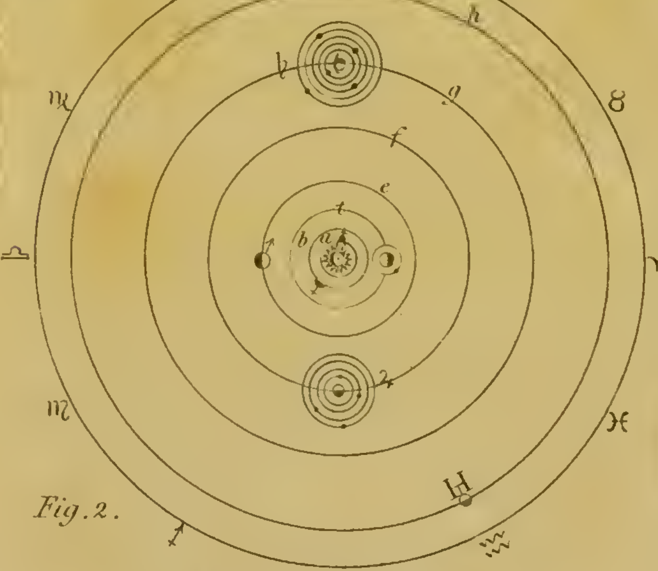

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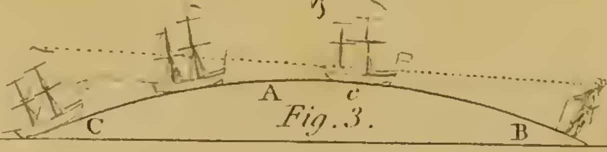

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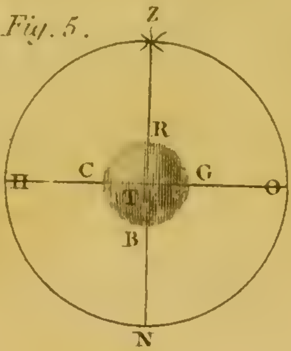

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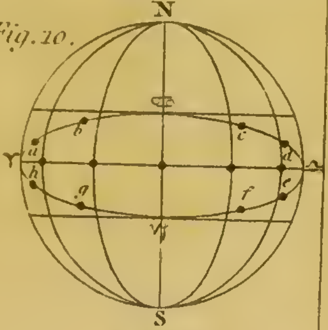

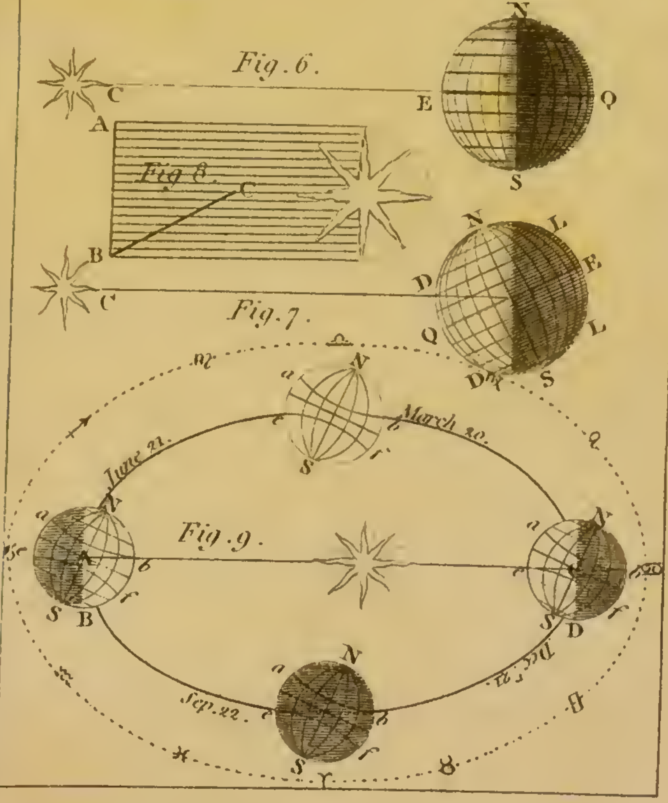
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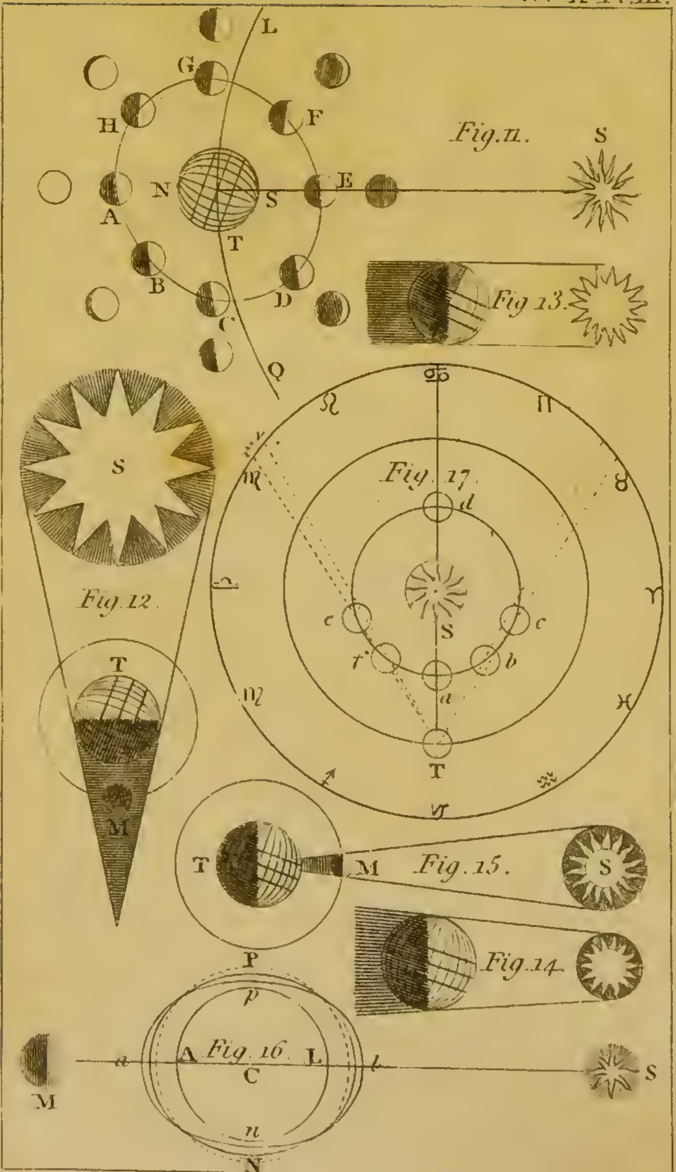
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Fig. 18.

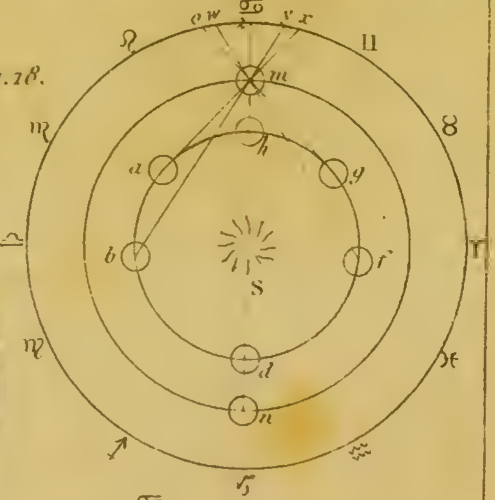
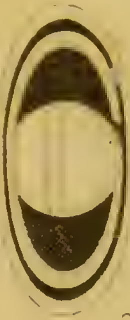


Fig. 20.



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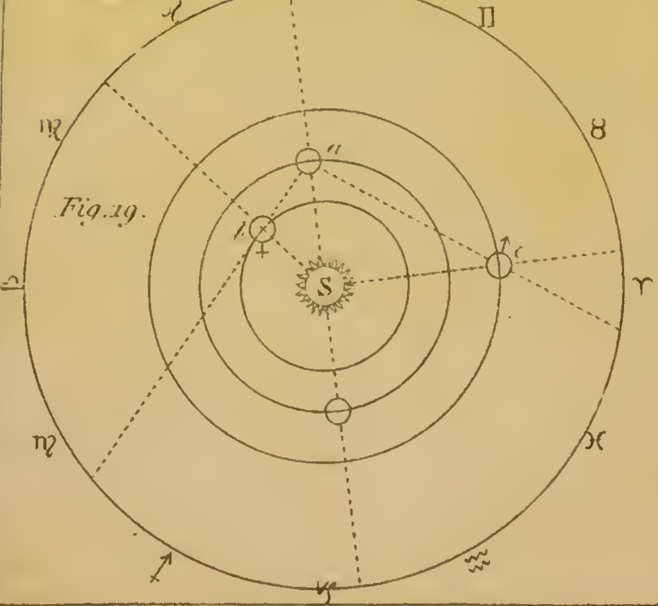

Lowry sculp